THE DECEMBER SCIENTIFIC MONTHLY

Edited by

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CONTENTS

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NEW BOOKS OF SCIENTIFIC INTEREST

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This book is for use by advanced students of experimental physics and the research worker who has studied general physics. It aims to give a concise account of the most important principles, methods and applications of geometrical electron optics.

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Glass Giant of Palomar. D. A. WOODBURY. Illustrated. $3.00. xii + 368 pp. Dodd, Mead.

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The Littoral Fauna of Great Britain. N. B. EALES. Illustrated. $3.50. xvi + 300 pp. Cambridge (Macmillan).

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This biography makes use of actual records left behind by Lord Rutherford. It has been written by a colleague who has since had access to these private memoranda and correspondence. He endeavors to give a personal representation of the scientist, and an account of his achievements.

Nutrition and Physical Degeneration. W. A. PRICE. Illustrated. xviii + 431 pp. Hoeber (Harper's).

By studying the diets of primitive tribes the author seeks to determine what foods are essential to nutrition and what deficiencies result from the lack of specific foods. Application to modern dietary problems is made.

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You're the Doctor. V. HEISER. $2.50. 300 pp. Norton.

Dr. Heiser offers methods of giving intelligent consideration to the matter of personal health. The book is addressed to normal people who want to keep themselves well, and are capable of realizing a much higher health standard than their present one.

What's Your Allergy? L. FARMER and G. HEXTER. $2.00. 234 pp. Random House.

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Intelligence and Crime. S. H. TULCHIN. $2.00. xii + 166 pp. Chicago.

The book represents a scientific attempt to deal with the problem of antisocial behavior in penitentiary and reformatory offenders. It is based on psychological tests given over a seven-year period, showing the relationships between crime and the intelligence of the offender.

Patent Fundamentals. A. SCHAPP. $2.00. 176 pp. Industrial.

This is a treatise intended particularly to aid the inventor in securing a correct understanding of the problems involved in obtaining proper patent protection. By practical examples and a discussion of court decisions it illustrates ways of defining and protecting an invention.

THE SCIENTIFIC MONTHLY

DECEMBER, 1939

WHAT CHEMISTRY IS DOING TO US AND FOR US

By Dr. ROBERT E. BURK

PROFESSOR OF CHEMISTRY, GRADUATE SCHOOL, WESTERN RESERVE UNIVERSITY

WHILE I shall not pretend to rate chemical feats in their order of importance, we may start with the fixation of nitrogen. This is done mainly by converting nitrogen from the air and hydrogen from water into ammonia, by the Haber process. This may be used as such or converted to various compounds. Nitrogen in these forms is assimilable by plants and can be made in unlimited quantities. Other elements not universally available are required by plants in much smaller quantities. The ammonia process is the chemist's refutation of the Malthusian principle that populations tend to outrun their ability to maintain themselves. Since no one can set a limit on the amount of ammonia chemists can make (the world is now over-supplied), no one is justified in accepting the Malthusian principle.

The opening of the World War in 1914 coincided with the large-scale manufacture of ammonia under the guidance of Professor Haber. This was no accident, since nitric acid, necessary for explosives, is made from ammonia, and without this process Germany would have been obliged to get nitrates from Chile through the British blockade.

The synthetic ammonia industry started in this country about 1922, with a production of about 5,000 tons per year. This had about doubled by 1925, had increased to 130,000 tons by 1930 and at the present time amounts to nearly 200,000 tons a year. This is a typical growth curve for an industrial chemical. The leading manufacturer is said to have spent $27,000,000 on synthetic ammonia over a period of ten years before it began to break even.

The World War showed the value of mechanized fighting equipment, particularly airplanes and tanks. Germany had no appreciable internal supply of petroleum, but they did have coal. The Germans, consequently, carried out large-scale research work on making gasoline and lubricants from coal. They have succeeded in developing two successful processes, the Bergius and the Fischer-Tropsch. Germany is making more than 2,500,000 tons, or more than eight hundred million gallons, of gasoline a year by these processes. If this state of preparedness again coincides approximately with a war, don't shoot the chemist—remember he has no strong voice in politics in Germany or elsewhere.

There has been much concern over the dire consequences of the exhaustion of our own petroleum resources, and the date has been set for the funeral several times. However, we can convert coal to petroleum by the German processes for a sum not much greater than the present tax on gasoline, so when the day arrives, all

we shall have to do is to induce our government to economize, take the tax off gasoline and we shall never know the difference. Whether that will be easy or not I do not know. There is enough known coal in the United States to last us more than 3,000 years at the present rate of consumption, and when it is all gone, we can find the rest of it or raise plants for conversion to alcohol or burn wood directly or use shale oil or use various other schemes. All the petroleum which has ever been used is approximately equal to one cubic mile. I personally have seen mountains of oil shale in Colorado which must represent many cubic miles, but it will probably be used only after most of the coal is gone, if at all. In any case, if our chemists have an opportunity to function we shall not lack energy to run our cars in 1950, the year 2,000 or the year 3,000.

While speaking of gasoline, I should like to say something on cracking and anti-knocks. The work of William Burton and others on oil cracking and of the General Motors research staff and others on anti-knocks has resulted in an average increase of some 10 per cent. in the power derived from a gallon of motor fuel at the present time and has about doubled the yield of gasoline from crude oil. This amounts to a gain of roughly a billion horse-power in this country alone. Now it seems that there is a remarkable river named the Tennessee which runs through Tennessee but drains all forty-eight states, a power which is derived from a body known as the Tennessee Valley Authority. Without attempting to weigh the price against the glory of this authority, I have added up the approximate horse-power in the contemplated electric installations of all the TVA dams, *i.e.*, Wilson Dam, Norris Dam, Wheeler Dam, Pickwick Landing Dam, Gunterville Dam and Chickamauga Dam, and the sum of all these monuments is about 715,400 horse-power. This is less than one tenth of one per cent. of the horse-power gained from the anti-knock and cracking research. Moreover, I have never heard a single politician eulogize William Burton or the General Motors Corporation for their work in conservation. In any case, we shall plainly be dammed in a big way if politicians try to equal the power conservation feats of the chemist by building the thousand odd TVA's which would be necessary.

Chemical industry, until recently, was almost synonymous with the dyestuffs industry. This child of Sir William Perkin is so much in evidence that little need be said about it. Purple used to be referred to as "royal" purple because only the upper class could afford it and it was prized accordingly. To-day all colors are so cheap that choice of color may surely be esthetic and not influenced by the prestige of high price. The American dye industry started only when the German supply was cut off during the World War. In 1925, we produced about 12,000,000 pounds of dyes per year, which rose to 32,000,000 pounds in 1930, and to 100,000,000 pounds in 1935. This typifies the vigor of a chemical industry. The leading manufacturer (du Pont) is said to have spent $45,000,000 on this industry over a period of 18 years before it began to make a profit. I do not know whether this is a reflection of bad judgment or of courage and wisdom, but I have given it credit for the latter.

Metals and metal products in 1935 sold for about $13,500,000,000. To a chemist, metals are chemicals as definitely as sulfuric acid is. Iron, copper, aluminum, chromium, nickel, silver, magnesium, gold, all form the basis of industries, but they likewise find places in the periodic table of the chemist. It would be tiresome to dwell on the details of the contributions of chemistry in developing stainless steel, high-strength steels, steels resistant to high or low temperatures, or to discuss in detail nickel, chromium,

zinc, cadmium and silver plating, commercial magnesium and aluminum, etc. But it may be permissible to point out that a new, though a very small, baby of the metals field, beryllium, is being reared in Cleveland, and from it can be made such interesting products as tools which do not give rise to sparks and springs which are resistant to fatigue. It is lighter than aluminum or magnesium. I might apologize for even mentioning gold as an important metal, but it will be remembered to have once attained that stature, and much public money has been spent for its purchase even in recent years.

The present era has been referred to as the plastic age. I don't know at the moment whether this is meant to refer to our susceptibility to propaganda or to the fact that the use of plastics or resins is increasing so rapidly. In any case the latter trend is shown in Fig. 1.[1]

The figures represent millions of pounds and do not include allied products such as asphalt, synthetic fibers and rubber. The popularity of resins is, I believe, due essentially to the fact that they provide a wider range of properties in materials than we have ever had before, and moreover their quality can be controlled. With all this, prices fall as production increases.

Synthetic resins have been used in some rather spectacular ways. I might mention lenses for spectacles, clearer and cheaper than ever and unbreakable. We now have plastic lenses fitted directly to the eyeball. Some resins have optical properties formerly expensive to obtain, *e.g.*, ultra-violet transmission and ability to conduct light around corners (Lucite). I have a transparent oil can, an invention which may spare an oath or two. Certain vinyl resins have the property of being nearly completely tasteless and odorless. This makes them specially suited for dentures, toothbrush handles, etc. Synthetic resins provide adhesives which can be heated with water without soaking off. Some of them are the most satisfactory insulating material yet found.

Moreover, one should not fall into the error of regarding a resin of a given chemical type or trade name as a more or less constant thing, such as some particular species of wood. Most of the resins are backed by research staffs which are constantly improving them. I imagine many would think the idea fantastic that metals will be replaced by resins in many of their applications. But resins are light, readily fabricated in mass quantities, do not corrode, are often

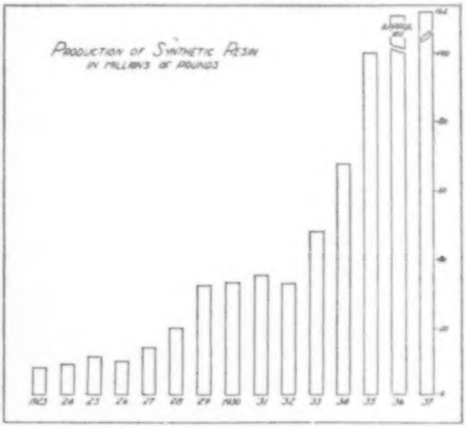


FIG. 1

adequately strong for the purpose and have other interesting properties. Actually, there are already many companies engaged in fabricating products from resins which were formerly made from metals.

Synthetic rubber is a close relative of synthetic resins. Four different varieties of synthetic rubber or near rubbers are produced in this country on a considerable scale, a fifth is produced in Germany and a sixth in Russia. It is interesting to note that only one of the six was developed in the laboratories of a rubber company, just as one of the most important recent developments in producing oil came from a chemical company, and one

[1] From the magazines *Chemical Industries* and *Industrial and Engineering Chemistry*.

of the most interesting chemical developments (synthetic glycerin) came from an oil company.

Synthetic textiles are related to, and in some instances are chemically identical with, synthetic resins and plastics. They are simply made in filamentary form. That rayon manufacture is a large industry is scarcely news. The present production is at the rate of about 300,000,000 pounds per year, which is about three fourths of our wool production, though still small in comparison with cotton production. It may not be generally known, however, that linen, cotton and other goods can all be simulated and probably improved in rayon.

Another interesting newcomer in the textile field is glass cloth, which is actually 100 per cent. glass. The factory in which this material is made was converted from a bottle factory. The material is of course absolutely fireproof. Its main use so far has been in electrical insulation. Electric motors insulated with glass cloth can be made with twice the power for a given size because they can be run hotter without damage to the insulation. The material is also useful wherever cloth is desired which is resistant to light, heat, chemicals, etc. It is not anticipated that suits and dresses will be made of glass.

The glass industry has been progressive in other directions. Safety glass, in which a layer of plastic material is sandwiched in between two layers of glass, has saved many lives. It has been improved until it is unaffected by light. A new variety yields so much under impact that the blow experienced by a passenger thrown against it in an accident is definitely softened.

We have glass which is resistant to mechanical shock, glass which is resistant to temperature, and recently glass which you can not see. No doubt you have seen with approval some buildings utilizing translucent, insulating glass brick. Insulation in housing is a development which was surprisingly slow in view of the established principles of insulation, yet one which no doubt is destined to make an important contribution to comfort and to the conservation of our fuel resources.

The trouble with building is that it is done largely by relatively small organizations without important research facilities. Consequently, houses improve slowly in comparison with, say, automobiles.

Air conditioning is a substantial and a growing industry which is partly, though not entirely, chemical. It doesn't mean much as yet in the North. One must go South in the summer time to appreciate it. It is, however, a development which seems destined to make important contributions to health in cities. Closely connected with this topic is the art of refrigeration. Artificial ice was an important development for health and comfort, but a private ice plant in your home is a better one in the eyes of some millions of users. Imagine a hospital without refrigeration! More recently we have the preservation of foods by quick freezing, a process which most observers would agree preserves food with a much closer approximation to the original taste than canning.

One could scarcely review the practical accomplishments of chemistry without mentioning photography and its vigorous child, the motion picture industry. Active research has made colored photography practical, and active research is being conducted to improve it. We have a professor who finds this scientific creation a relief even from literature. The leading photographic company in this country employs more than four hundred research scientists.

Medicines, antiseptics, hypnotics, vitamins and hormones are amongst the brilliant triumphs of chemistry as a partner in the field of medicine, but I shall not dwell on them at present.

While I have hit only the high spots in chemistry's contributions to modern society, it might get tiresome to discuss finer details. As to the magnitude of applied chemistry, if one defines chemical industries as those in which the products or processes can be described in definite chemical terms, he would be obliged to include chemicals proper, petroleum, rubber, glass and ceramics, metals and textiles, but not the fabrication of metals and textile products. The products in this non-inclusive chemical group were sold in 1935 for approximately thirteen billion dollars. This is an impressive fraction of our national income, even though many partly chemical industries have been omitted from the list.

What can be said on the side of chemistry which some consider to be detrimental? Opinions, of course, vary as to the value of different inventions. For example, I don't like dial telephones or gelatin in ice cream. Others dislike radios; still others automobiles.

The alleged major crime of science has received the high-sounding name of technological unemployment. The idea may be illustrated by the cigarette industry, where high-speed machines have been introduced which produce prodigious quantities of cigarettes per man employed and which industry has experienced a steady decrease in employment. Aside from the fact that few would wish to condemn men to a life of wrapping cigarettes by hand, this example, however, is a most unfair representation of the situation. In this industry, the demand is rather flexible, and the public would not applaud strenuous efforts to expand it. The rayon industry or the automobile industry would make a very different impression. Fig. 2 (from *Chemical and Metallurgical Engineering*) shows the trend of production and prices in the rayon industry and is typical of a scientific industry where demand increases as prices decline and quality improves, as the result of intensive research. A similar diagram showing the still more striking increase in the production of synthetic resins has already been presented. Whether more or fewer men will be employed in course of time in such an industry as a result can not in general be predicted.

According to the October, 1938, number of *The Chemist*, a publication of the American Institute of Chemists, the horse-and-buggy business gave jobs to around one million persons in 1900. In 1937, the automobile industry furnished

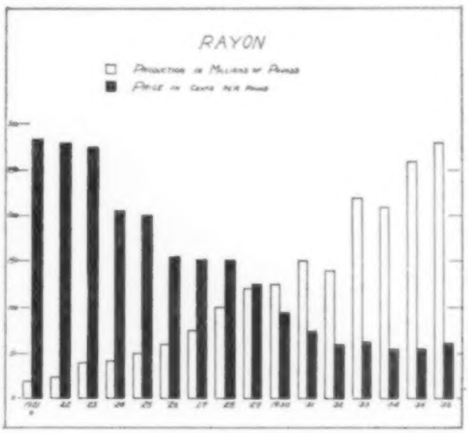


FIG. 2

employment to over six million persons in making, selling and servicing cars. Moreover, a million persons are employed directly in the petroleum industry. In addition, many thousands of man-years are expended in what to some people is the pleasant pastime of riding around in automobiles.

Any balanced discussion of alleged technological unemployment likewise must consider new industries created by science, of which there are many. Of these the recreation industries, which already involve more than 8 per cent. of our national income and which lap over with the field of education, should be pondered by those who are inclined to

worry over alleged unemployment resulting from applications of science.

I visited one of the large continuous steel strip mills which stand out as a high achievement in mechanized processing. It would be easy for a breast-beating agitator to infuriate a mob over them. A huge output of finished steel comes out of these gigantic machines with scarcely any one in sight. Since here is an industry where the demand is flexible, I inquired as to the overall effect of this equipment upon employment in the steel industry. I learned that employment in the steel industry as a whole increased 23 per cent. from 1926 to 1937, whereas employment in four leading steel companies, operating continuous mills for all or part of the period, increased 28 per cent. in the same period. This takes no account of the huge capital expenditures involved in the mills themselves, representing more employment.

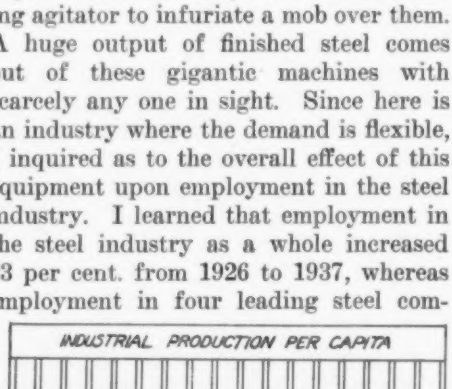


FIG. 3

The true situation with regard to technological unemployment appears to be that as a national factor it doesn't exist. As Dr. K. T. Compton, president of the Massachusetts Institute of Technology, and others have recently pointed out, "statistics show no decrease in the fraction of our population gainfully employed during the last few generations in which machine production has become important." The magnitude of the increase of manufacturing efficiency during this same period is very large, as shown in Fig. 3, from an issue of the *Business Bulletin* of the Cleveland Trust Company.

One factor seldom discussed in connection with alleged technological unemployment is the increasing number of women in industry. Leaving out the field of domestic service, the number of women now employed is at least equal to the total persons unemployed. If women are better fitted to do some of the work men used to do, they will probably do it in the end, and the less competent men, I suppose, may have to do the dishes and take care of the babies. But in any case, I do not see the justice of blaming the chemist for that situation.

The harshest thing which can be said of science with respect to technological unemployment is that sometimes men are obliged to shift jobs. We wish, however, to do something about some ten million people who may desire to work. The scientist interested in the economic effects of his work must be impressed by the effect of taxation of industry on employment and as a repressing factor in the application of science. This is relevant to the present discussion, because it is an insidious force which tends to stunt the normal growth of scientific industry. The factor is particularly striking in the petroleum industry. Here the application of scientific methods has reduced the average retail price of gasoline from more than 29 cents in 1920 to less than 14 cents in 1937, or about one half, the figures being without the large retail tax. This technical triumph has been in spite of rising labor costs and rising indirect taxes, and the quality has improved. But much of the gain has been offset by direct retail taxes, which in some states amount to nearly twice the wholesale price of the commodity in spite of the fact that gasoline is now a necessity for most people. This industry pays total taxes amounting to much more than the total net income

(after taxes) of the industry. While tax money is also spent, it must be particularly emphasized that it is not spent in the discriminating way which encourages the growth of those particular industries which should grow, namely, those capable of expansion through flexible demand, lower prices, improved quality and new uses. One does not have to be expert in the field of economics to perceive that such predatory government policies as are exhibited in the petroleum industry produce unemployment, for which the scientist is blamed, instead of the politician.

A third alleged crime of chemistry and science in general is the destruction of capital through obsolescence. I can at last agree that though more wealth is created than is destroyed, this is a well-taken criticism. If the executives of a company insist upon ignoring scientific research and the improvements in their products and operations which scientific research makes possible, and their stockholders allow them to take this attitude, then there is little doubt but that their business will not prosper as it otherwise would. But the privileges of thus dying is not wholly a bad thing. It would require a high order of oratory to provide an equal degree of persuasion to business men that they should engage in large-scale research.

Ten years ago, *Barron's Weekly* conducted a contest on the problem, "How to Invest $100,000 for a Widow." The man who gave the best answer as judged by the ten-year record was recently asked to give a new answer for the next ten years. He then advised that she invest $70,000 in a well-diversified list of common stocks chosen almost entirely from those companies which are known to be in a good position to benefit by scientific research and development.

But that is only an opinion. Some facts may be more forceful in illustrating the conspicuous success of research in industry. For this purpose, I have examined the financial records of certain companies, of which some are conspicuous for aggressive research, others of which are not. The companies are all representative and prominent in their respective fields. It does not represent an exhaustive study of all companies in the country, which, so far as I know, has never been made. It is difficult, likewise, to find companies which pursue opposite research policies in the same industry. Finally, I do not pretend that the quality and quantity of research is the sole factor in the financial records of these companies. The figures are from "Standard Corporation Records." I have examined the net earnings of the Dow Chemical Company over the past five years, which did not come even near to sustaining a loss in the great depression. It is spending about $1,400,000 a year on research, with net sales of about $25,000,000 a year.

The E. I. du Pont de Nemours and Company has had a continuous record of net income since 1926. It is noteworthy that their 1936 and 1937 earnings exceeded their 1929 earnings. Their research expenditures are at the rate of more than $7,000,000 a year, and their net sales about $286,000,000. I think it is safe to say this company spends more money on chemical research than all the universities in the country combined.

The Union Carbide and Carbon Corporation has had a similar record. Its 1937 earnings were at an all-time high. This company has never incurred a loss or passed a dividend. Their research expenditures are not available, but are high.

Next, let us look at a large railroad company. Railroad earnings may be complicated by having to deal with strong labor unions and government control. Nevertheless, though they are themselves merely exploiting an invention, they are not known to be aggressive in

research. The New York Central Railroad had a deficit of about $18,000,000 in 1932 and only a meager return in 1937 in comparison with 1929.

The Pittsburgh Coal Company, one of the largest coal companies in the country, has had a deficit every year but one since 1925. If research is carried out by them on a large scale, I have never heard of it and it is not mentioned in "Standard Corporation Records," nor in the National Research Council Records.

The Long-Bell Lumber Company, one of the largest in its field, has had an almost continuous record of heavy losses since 1925 and has had to go through reorganization. Lest it be concluded that the record of this company is the inevitable result of the decline in building, let us examine the record of the net earnings of the Johns Manville Company, also dependent upon the building industry, but well known for its aggressive research policy. It has had no deficit since 1926 and in 1937 it is to be noted that its net earnings approached the all-time high.

The very least one can say is that all this evidence is in favor of the idea that aggressive research work in industry pays very well and preserves the capital of those who practice it.

Another danger of applied science with which I might agree is that there is a tendency to try to get along with too little knowledge. We may be in a critical period now in this regard. Thus I take vitamins every day and am under the impression that my health is improved thereby. But I should feel more comfortable about this practice if knowledge on the subject were more extensive. The generalized point is that we are heavily involved with science and it seems wholly illogical and impractical to try to turn the clock back. Yet our knowledge is so scant that we may pinch our fingers here and there trying to make the machine work, unless we have more definite information with which to run it.

It would reflect no credit on chemistry if I were to attempt to disparage other branches of learning, which is far from my intentions. Nevertheless, the impression is growing that current leadership in the fields of business, politics, labor unions or education, if you please, can not be effective without large masses of incontrovertible facts, without sound scientific guidance.

Though it has been said that "pearls of great price can not be had for the asking," the material pearls which science has produced have been sold very cheaply. In the past, inventors' receipts from important inventions are commonly less than a broker's commission for handling articles of commerce. But the most valuable pearl which science has produced is dangling in front of us absolutely free, yet largely ignored. This is the demonstrated value of facts as against opinions. This is the key to the growth of science. Why isn't this principle more contagious? Why can't some of the billions which the public seem willing to squander on a gleam in some politician's eye be devoted to the acquisition of such a body of tangible facts as will guide us properly?

The high valuation which we should place upon facts brings a defender of chemistry to questions of the influence of science on the moral and spiritual well-being of man. Millikan, Compton and others have written and spoken on the lack of conflict between science and religion, and a technical discussion of that subject will be avoided. However, some writers, beginning at least with Robert Southey, have bemoaned the rise of the scientific age as a destructive force in the spiritual progress of man. This force is represented as attaining a hurricane stage in the mass production industries of the present day. But while some authors may not like to run lathes, it is my personal observation that lathe hands are not a particularly unhappy lot. Labor

generally is probably at least as well off as in the days when they endured the burdens of the Middle Ages. I should go much further than that and represent science as an exceedingly powerful spiritual and moral force. If a man doesn't learn moral lessons from the observation of the certainty of operation of natural laws, he seems to me to be morally hopeless. The qualities which we commonly associate with high character are, according to my observations, especially marked in persons who have a deep appreciation of facts. Which is cause and which effect it is difficult to say, but in any case, the two are compatible.

I believe Abraham Lincoln emphasized strongly the importance of respect for law. But this advice can be followed only if the laws are respectable. Even the time-honored and respectable man-made laws are broken and it takes a lot of policemen to enforce such observance as we have. Now it is an indisputable fact that people do not try to break natural laws if they have any comprehension of what these laws are. Surely the lunatic who tries to fly with an umbrella will not be cited against me at this point. Is it too much to hope that legislators and the public at large will, some day, grasp the implications of this comparison; that they will think again before they say "there ought to be a law"?

The spiritual stimulation of what are sometimes referred to as "cold facts" may not be so obvious as their moral effect. It is well known that producing scientists are inclined to work hours which would cause a popular uproar (to say nothing of violating a federal law) if employers imposed them on their employees. Is this because scientists are simply queer animals? Possibly they are a little queer, at least the rest of them may be, but I imagine the effect is due to a degree of interest which is difficult for those not similarly stimulated to understand—an interest derivable from the "cold facts" of science, though, of course, not alone from science. It is difficult to purchase equally satisfactory amusement, as Lord Cavendish, the Duc de Broglie, the Prince of Monaco and other men possessing both wealth and intelligence have found out.

Perhaps I can illustrate the stimulating effect of cold facts by means of an example. The course of political and economic events over, say, the next decade will assuredly follow some pattern or other, and most of us wonder what it will be. For the sake of illustration, let us suppose that an exponent of some branch of political science could predict such a course of events with certainty, and that there was general confidence that he could do so. (I must apologize for the fantastic character of this illustration.) But in that event, I think all would agree that a lecture on that subject would arouse the most intense public interest. The cold facts alone would have that result—no high-powered oratory would be required.

Unfortunately, I am not sufficiently skilled in the proper field of political science for such a valuable prophecy, but in the field of chemistry sufficient information has emerged from research laboratories to justify some predictions.

I pointed out that hundreds of millions of horse-power have been created by the efforts of chemists in the field of motor fuel. There is a steady advance in this field which must continue for some time. Diesel engines have been held back by such factors as higher first cost. This is due at least in part to the circumstance that they have not been produced in large numbers. In other words, the spark ignition engine got there first. The problem of mixing the fuel and air is a problem in the Diesel engine which, however, does not seem to be inherently insoluble. Diesels have been increasing in number, and I should hesitate to predict the end.

Medical research is bound to make fur-

ther strides. Industrial medical research has grown rapidly in such laboratories as Abbott, Lilly, Squibb, Parke-Davis, etc. Since the public wish to be cured and are quite willing to pay for being cured, I should not be surprised to see a very large growth of medical knowledge emanating from such laboratories. Less research is carried out on making the human machine run properly than on making automobiles run properly, yet surely automobiles are less important than human beings. The obvious difference is that research on automobiles and their fuels and lubricants is commercialized—I should say decently so—while medical research has been to a considerable degree restricted by what their authorities consider to be ethical taboos against commercialization. I hope it will be possible for academic medical research to be so related to the industrial medical research that it will not be eclipsed and can be adequately financed. As a subject for a future Nobel award in biochemistry I should like to suggest a pill which would soften the emotion of jealousy.

Chemical control of plant growth is one of the most promising research developments of current interest. It has gone far enough to make one sure it is going farther. It seems that the extent of growth of plants does not proceed to some inherited limit, as with animals, but is rather related to their food and light supply. Moreover, plants in some circumstances may be fed intensively from solutions more conveniently than in soil. This technique is an established commercial success, *e.g.*, in raising tomatoes. Plant hormones with their specific effects upon plant growth add to the fascinating future of this field.

Allied chemical industries of future interest will be those based upon agricultural raw materials. Illustrative infant industries are the soybean industry, the tung-oil industry and the production of furfural on a large scale from oat hulls. Cellulose, the main constituent of cotton and wood, is the basis of paper, rayon, Cellophane and the cellulose plastics, *e.g.*, cellulose nitrates (celluloid), cellulose acetate and other esters; ethyl cellulose and cellulose ethers. These industries are still expanding. Agriculture, including forestry, it seems, can best continue to supply the raw material for these products. Who can deny that if the next billion dollars appropriated for farm relief were spent instead for research on the better utilization of farm raw materials, the result would be a cure instead of relief for the farmers?

Alcohol and sugar are made from wood in Germany, but whether alcohol will eventually be made from molasses, beets, Jerusalem artichokes, sweet potatoes, petroleum, wood or coal in this country has not been made clear.

Protein chemistry is being studied extensively at the present time. Something will come of it, but the work has not settled sufficiently to say just what. The physiological response of protein-like structures and of particular chemical groups in proteins is obviously important.

The probabilities for continued lowering of costs and still further increasing variety and quality of textiles and plastics are plain. It requires no special psychic power to predict that both industries will continue to grow in importance. Synthetic fibers will probably replace natural ones more and more completely for at least four reasons: (*a*) They are more uniform in quality; (*b*) they are continually improved in quality, whereas cotton and flax plants, sheep and silkworms are not quite as progressive; (*c*) synthetic fibers may be built with qualities not possessed by natural fibers; and (*d*) manufacturing costs will probably fall faster than farming costs.

One of the most spectacular of the newer fibers is called nylon. Rayon, being made from cellulose, is not entirely

synthetic, some of it having the same chemical composition as cellulose. But this new fiber is made entirely from coal, air and water. It is a polyamide material related therefore to proteins in structure. Its first application is in the lowly toothbrush, since bristles made from it do not soften when wetted. This is, of course, more than can be said for hog bristles. More interesting to the household budget is that women's hose can be made of the material which are more durable, though more sheer, than present ones. It is likewise expected that this substance will be admirable for tennis racquet strings, since it is strong and elastic yet uninjured by water. Finally, the material can be spun finer than silk or rayon. Large-scale production of this substance is expected to start early in 1940.

Important research is being carried out on wood itself. The use of synthetic plastics instead of glue has greatly extended the field of plywoods. These can be made of uniform and high strength so that objects made from plywood can be engineered as precisely as objects made from a metal. Progress is likewise being made in giving to wood other desirable qualities. Thus this substance can either be improved or dissolved and converted into a host of other things.

Synthetic chemical products will increase not only from agricultural raw materials but from petroleum and from coal. In fact, there will be probably some lively competition among these raw material sources. Thus, glycerin from petroleum has recently been announced in competition with agricultural glycerin.

In the field of metals, corrosion seems to be an outstanding trouble at the present time. When a trouble is as expensive as corrosion is it can safely be predicted that research work will continue to be concentrated there. One can see no particular reason why quests for new alloys should stop.

Chemists would be dull indeed if they can not further lighten the burdens of the housewife. Our rugs are treated with a chemical which makes them permanently immune to moths. Shrinkless blankets have recently been announced. These are cases in point.

These predictions are merely a few reasonably safe ones. The unpredictable developments are quite likely to be of as great or greater importance. Moreover, these predictions are predicted on the preservation of reasonable patent protection on the part of government, without which, in the nearly unanimous opinion of chemists, industrial research can not function. In an invention, one creates property which did not exist before. How could there be a stronger title to property? It seems incredible that persons who recognize weaker titles (or do they) to such property as real estate should wish to deny patent protection to inventors.

Nevertheless, there has been a movement in Washington to diminish the patent rights of inventors. Under the McFarlane bill, turned down by the last Congress, a government agent could license your patent to your competitor for a dollar if he so chose. Mr. McFarlane did not return to Congress, but there is a new patent bill and propagandists are at work on the subject of patents, from which I suppose we can conclude that some higher-up has a weird idea and is exerting back-room pressure against patents. This patent conspiracy to my mind is the most serious threat to the proper development of science which we have at the present time. If the plot is successful, it would cause a subtle economic disease comparable with keeping industry on a vitamin-free diet. The disease would soon affect academic scientists.

Research policy is interesting in that the magnitude of research expenditures bears no particular relation to research

opportunity. The determining factor seems to be the insight and progressive quality of the management. Industries which have but recently emerged from the laboratory are particularly likely to take an aggressive attitude toward research. When Horace Greeley told young men to go west the economic reasonableness of his advice was fairly clear. Today the corresponding opportunity lies in science and particularly in chemistry, but the opportunities lie behind such words as catalysis, polymerization, methyl methacrylate, polystyrene, ascorbic acid, etc. Twenty years ago a steel manufacturer or fabricator couldn't be

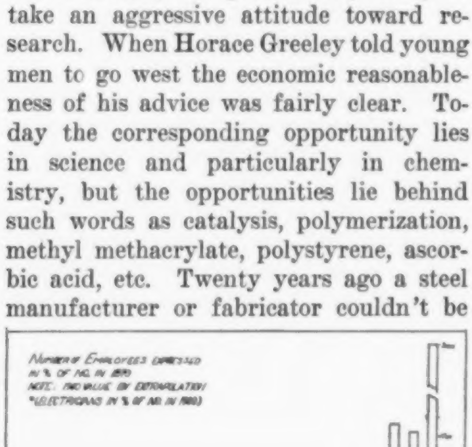


FIG. 4

blamed for not foreseeing competition from, say, phenol formaldehyde condensation products. Now we may blame him, because it has become clear enough that any industry is likely to be affected by research. Companies would now be well advised to build up research as fast as, but no faster than, they can assimilate it.

Research itself has become an industry as well as a means to industry. Industrial research expenditures are estimated at $250,000,000 in 1937. This is more than 10 per cent. of the expenditures on our entire educational system, though a paltry sum for the work at hand. Young men faced with the problem of picking a career would be interested in Fig. 4, which shows trends in the relative number of persons employed per million of population in certain representative occupations, including chemists. Research seems to be not only an interesting and prosperous frontier but an inexhaustible one.

What effects will industrial research have upon universities? Universities according to tradition are institutions for teaching and learning. But already more than 90 per cent. of the investigators are in industrial organizations. It seems that unless universities can tie in with the industrial work they will exercise the teaching function, but what they should be teaching, in the chemical field at least, will be buried in the files of corporations.

The old distinction between pure and applied research can no longer be drawn. The most argumentative would agree that biology is fundamentally dependent upon catalysis, polymerization and oxidation. This is because proteins and cellulose are polymers, because enzymes, hormones, vitamins, chlorophyl, the important trace elements and the like are properly classed as catalysts, and because oxidation is the fundamental energy-producing reaction. Yet it is my impression that information on these subjects is accumulating faster in industrial laboratories and projects than in non-industrialized medical research institutions. This impression is based on some years of experience in coordination information in these fields.

A friend of mine who is in a position to know has told me that the volume of new publishable chemistry which is, each month, locked in the files of one of our large chemical companies, alone is equal to all that which comes to light through the *Journal of the American Chemical Society*. The chemistry of aliphatic hydrocarbons as we know it to-day has de-

veloped largely in industrial laboratories. The petroleum industry has recently developed an easy technique for converting aliphatic hydrocarbons to aromatic ones, a contribution to chemistry of which any university laboratory in the world would be proud. One company has recently published a new system for quantitative analysis by means of x-rays. Some of our most useful technique, such as the easily available high vacuum technique, has come from industrial laboratories. Automatic instrumentation, developed by industry because it is necessary for precise plant control, is rendering research experiments and observations more accurate than the most zealous human observer could make them.

It is idle to suppose in the field of chemistry at least that the able theoretical men stay in universities, while the second-rate ones go into industry. Nobel prizes not infrequently go to industrial men these days—Langmuir, Bergius, Davidson come to mind. Bright young men who spurn industrial work at the age of 25 are often in it at 35. I could name a long list of top-notch chemists in industrial laboratories. Does it not seem unfortunate that such men are not in general so situated that graduate students can have the benefit of their learning and experience?

Corresponding to the growing importance of chemical research and the function of universities in providing properly trained men for the work is also one of growing national importance. To do this work well, universities must maintain, or perhaps regain, leadership in chemical research. But, alas, this has become a large and expensive job—too large probably to be financed adequately by traditional methods in these days of open season on wealthy men. It seems to me that the work of theoretical science in universities is too important to industry to be nourished in the future as in the past merely by the crumbs which fall from the industrial table.

We have a new situation in the world of scholarship. Never before have hundreds of chemists or any type of scholar been gathered together in one spot engaged in the creation of new knowledge, a situation which exists in many spots to-day. Chemical abstracts cover some 200 journal articles and patents a day. It requires money and men to keep up with such a parade, to say nothing of leading it. It is too much to expect an isolated professor to make much of an impression on such a flood of information.

Universities have acquired a new problem in orienting themselves to large-scale organized research. They have perhaps a new rival, but also a new and much-needed and much-deserved source of support. Scholarship has become tangibly and nearly immediately valuable, and shrewd capital is responding to that realization.

Chemists have literally made a silk purse out of a sow's ear; they have literally made a duck sink instead of swim. One should not be surprised if they succeed in gaining for able college professors the public respect and economic status which they should have.

RUMFORD AS A SOCIOLOGICAL ENGINEER

By Dr. C. HARRISON DWIGHT

DEPARTMENT OF PHYSICS, UNIVERSITY OF CINCINNATI

To the physicist the name "Rumford" suggests, quite rightly, the experiment on the heat produced by friction. The Rumford photometer is also usually remembered. Beyond these two contributions to physics, nowadays described in every text-book, the average scientist is frankly ignorant. Except for fragmentary information about certain clever designs in stoves and chimneys, general knowledge of this amazing man becomes rapidly weaker, the final flicker of interest occurring at the mention of Rumford baking powder! Prodded by an occasional student, the physics teacher evolves the information that Sir Benjamin Thompson, later the famous Count of Rumford, was the founder of the Royal Institution of Great Britain, and refers to the Rumford Fund of the American Academy of Arts and Sciences.

Count Rumford was not only an experimenter but a scientist in action in sociological problems, applying the tremendous zeal, accuracy of observation and care in conclusions that characterized his entire scientific career to the baffling problems of social maladjustment. To the scientific attributes above-mentioned must be added, as of vast importance in the "extra-curricular" activities of Rumford, his tact, unfailing courtesy and knowledge of human nature. The last characteristic may be illustrated by his own words:

> All sums of money or other assistance given to the poor in alms, which do not tend to make them industrious, never can fail to have a contrary tendency, and to operate as an encouragement to idleness and immorality.

Charles Theodore of Bavaria, looking out from his none-too-secure position as Elector upon the world of his time, sensed a situation that boded little good to sovereigns. A few miles away the French monarchy was beginning to tremble, and far off across the ocean to the west, on the semi-civilized fringe of a continental wilderness, a few thousand colonials had dared resist the government of their mother country. Unrest was in the air—a world epidemic that would break out whenever or wherever the conditions became acute. The Elector was full of concern for his three million subjects. Not only was his land harassed by internal troubles, but the neighboring states of Prussia, France and Russia were by no means friendly.

In September, 1783, Colonel Benjamin Thompson, a fine-looking British officer on extended leave, arrived at Strasburg from England. By his geniality and knowledge of practical affairs he won for himself acquaintances among the strangers, among whom was Prince Maximilian of Deux Ponts, nephew of the Elector of Bavaria. Continuing his journey into the latter country, Colonel Thompson presented letters of introduction to the Elector, who speedily found from personal contact that he was dealing with the very man who could help him settle the chief problems confronting the country. Agreeing to give his aid, Thompson spent the next four years in a careful study of all the economic and social forces at work in his patron's dominions, as well as of the language, mineral resources and industries.

There were in Bavaria at that time two major social problems: the employment of the army in days of peace and the importunities of thousands of beggars.

In order to solve the second problem, the first had to be thoroughly mastered. Realizing that the maintenance of a large standing army was a menace to the people, financially and economically, Thompson instituted drastic reforms. Soldiers, though recruited from the soil, refused to return to the simple life when on furlough. Colonel Thompson realized that they must be made to see the *desirability* of such a return. With the complete acquiescence of the high-ranking officers, he declared that military life would henceforth be shorn of obsolete and useless customs, that each man would be given as much liberty as was consistent with order and subordination, that opportunity would be offered for self-improvement, and that schools would be provided so that not only soldiers, but their children and their neighbors' children, could learn at least the three R's. The government was to supply books, paper, pens and ink. Lest the soldiers should have idle time on their hands in spite of the new régime, a "Military Workhouse" was provided for them and their families. Raw materials were given to them by the government, the proceeds of the sale of the completed goods being entirely at the disposal of the workers. The latter were issued strong canvas working suits. The official duties of soldiers in time of peace were largely similar to those of the modern C.C.C.—making and repairing roadways, draining marshes and repairing the banks of rivers. The regimental bands played at times of unusually arduous work, while sports and games were encouraged on holidays. Ten months' furloughs were allowed, in rotation, to a large number of soldiers in each garrison, their time being spent in recruiting, in engaging in manufacturing and in agriculture in their home communities. To encourage this last activity, Thompson planned a garden in connection with each army post, so that the soldiers could experiment with potatoes, at that time quite a novelty. Each man was allotted 365 square feet, which he could cultivate for pleasure and profit. The soldiers took pride in their miniature farms and even took seeds and potatoes with them when they went home on furloughs. Thus new foodstuffs and better methods of cultivation were introduced to the populace. The men were allowed to seek advice and assistance from their officers, who were forbidden to accept any remuneration for their counsel.

The reformation of the army meant the first step in Sir Benjamin's plans for the elimination of mendicancy throughout the country. This evil was a gigantic and organized system of abuses, tolerated by the government and the people, which made life miserable, and even unsafe, for the majority of citizens. The local laws for the support of the poor were utterly inadequate to cope with the situation. Beggars and vagabonds, of both sexes and all ages, natives and foreigners, swarmed over the land, lining the roads, robbing houses, stores, workshops and churches. What they could not obtain by begging, they sought to acquire by threat. Since most of these ruffians were strong and well, and preferred their lazy life to one of industry, they were at once the terror and the scourge of the country. Children were kidnapped, maimed and then exposed to the public in order to extort a fixed sum per day. Terrible punishment was threatened if the stipend were not obtained. Even herdsmen and farmers levied contributions from passers-by, and farm children, too young to work in the fields, were taught to ask for money by the roadside. In the cities there were beggars' castes, with rules as to territory, intermarriage and professional privileges of offspring.

Thompson's first move was to dispose of four regiments of cavalry in such a

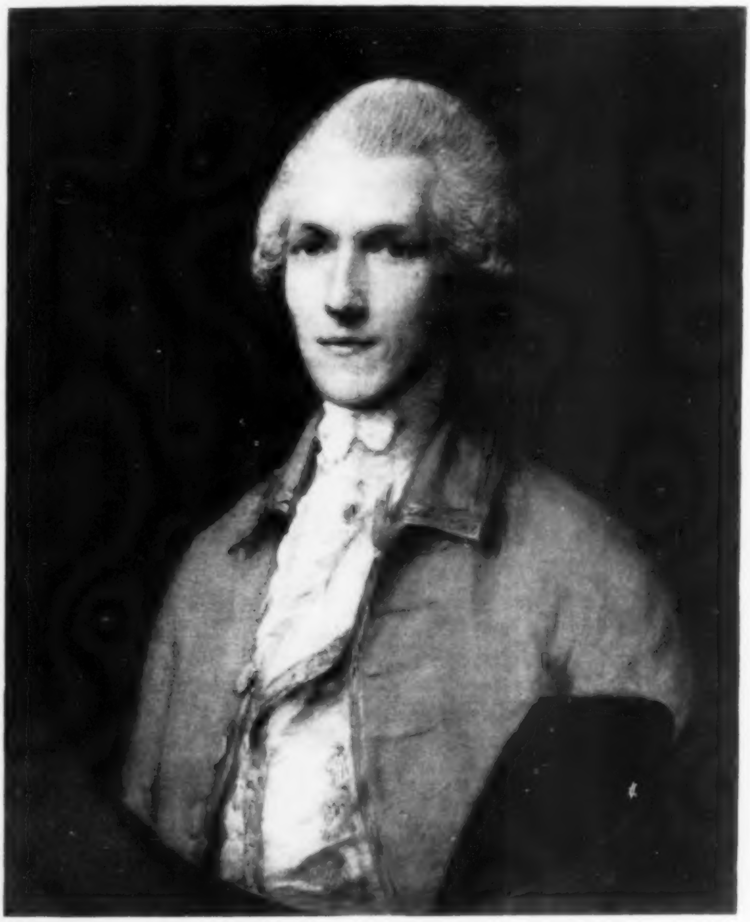
way that every town and village had a patrol party of from three to five mounted soldiers daily coursing from one station to another. The exaction of food, forage and lodging from any peasant's home was not permitted. Officers were detailed to inspect these patrols, and a general officer, having inspected all the cantonments, reported to headquarters at Munich. Printed instructions in great detail governed all these matters. The patrols had orders to convey government messages, guard the frontiers, prevent smuggling, assist at conflagrations and apprehend all bandits. The inhabitants of each district provided for the simple wants of the patrols, and so well and economically was the plan worked out that the entire cost to the country for one year was only a matter of some ten thousand dollars.

To take care of the worthy poor and to provide employment for them, especially in the cities, Thompson organized an efficient bureau composed of persons of the highest rank. This body, serving without pay, included the respective presidents of the Council of War, the Council of Supreme Regency, the Ecclesiastical Council and the Chamber of Finances, together with a councilor from each of these departments. A secretary, a clerk and an accountant were provided at the public expense. The city of Munich was divided into sixteen districts, and in each of the latter every dwelling house was numbered, whether it were a palace or a hovel. For each district a Committee of Charity was appointed, composed of a priest, a physician, a surgeon, an apothecary and a "respectable citizen" who acted as chairman. These persons likewise served without pay, and as a body were affiliated with the general committee. The worthy poor were given aid when and in such form as they needed it.

The vagabond class presented a different problem altogether. It was a great feat of "social engineering" to turn a multitude of persons who had been bred deliberately in lazy and dissolute habits, void of decency and the sense of shame, covered with filth and vermin, and sleeping in rags, into a happy and thrifty group of workers. The amazing fact is that Thompson's plans were very successful. His executive ability was so great, and his resoluteness and tact so unusual, that under his administration the seemingly impossible was accomplished. His general theory was that the vagabonds would be tractable if they were first made happy and comfortable. They were to be provided with pleasant, warm rooms, given a wholesome dinner daily and provided with a chance to do remunerative work if they desired to earn a living. A circular of appeal was issued throughout Munich, Thompson himself assisting in distributing the leaflets among the principal citizens. The response was encouraging. Old charitable institutions—religious and secular—agreed to give up their former house-to-house canvass for funds since they were to receive the equivalent sum from the public treasury. Bakers and butchers, delighted at the prospect of freedom from the beggars' importunities, agreed to contribute wholesome leftovers from their shops to the public kitchens. Thompson caused an old factory building to be thoroughly cleaned and repaired, and added a kitchen, bakehouse, dining hall and workshop.[1] Carpenters, smiths and other mechanics were installed, with the request that they make and keep in order all the tools and machines which the proposed "House of Industry" might require. Large halls were set aside for workers in flax, hemp, cotton, wool and worsted—each hall provided with an

[1] The Arbeitshaus and the Armeninstitut, housing these industries, are still standing in Au, a suburb of Munich.

overseer, whose duties were to give out the raw material, take in the finished work and account for the labor done. By designing efficient fireplaces, Thompson calculated that food for one thousand persons could be cooked each day with about five cents' worth of fuel. The House of Industry was also to contain dwelling-rooms, store-rooms, a drying hall, a fulling-mill, a dyer's shop and a wash-house—everything spick and span in fresh paint.



COUNT RUMFORD AT THE AGE OF THIRTY

THIS PORTRAIT BY GAINSBOROUGH HAS BEEN TERMED "ONE OF THE GREAT ENGLISH ARTIST'S FINEST ACHIEVEMENTS IN MALE PORTRAITURE." IT IS REPRODUCED HERE BY COURTESY OF THE WILLIAM HAYES FOGG ART MUSEUM, HARVARD MUSEUM.

These plans having been executed, the next problem was to collect the vagabonds! Rumford decided that the proper time for action would be the following New Year's Day (1790), nationally known as the "Beggars' Holiday." Orders were given that three infantry regiments station themselves at the street corners and that field officers and all the chief magistrates of the city be on hand to deal with each beggar who sought for alms. Rumford and his own partner set

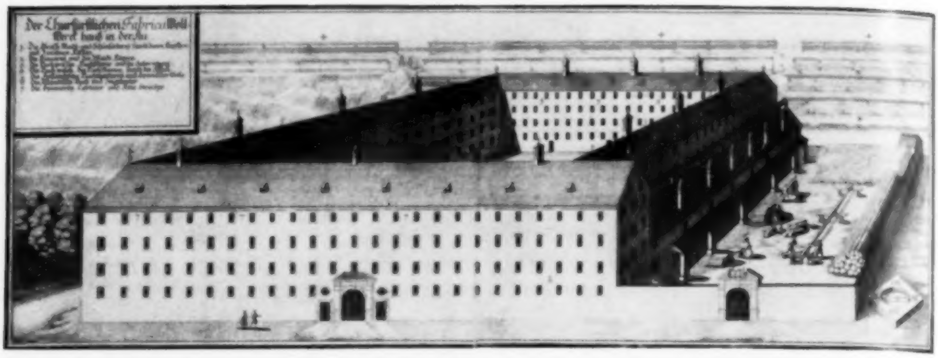


FIG. 2
THE BUILDING OF THE WOOL MANUFACTORY IN AU, ERECTED IN 1679, AND EMPLOYED BY RUMFORD AS A MILITARY WORKHOUSE AND INSTITUTE FOR THE POOR IN 1789. FROM A COPPERPLATE BY WENING. IT IS REPRODUCED HERE BY COURTESY OF THE GERMAN MUSEUM AT MUNICH.

the example for the others by walking out on to the street, where a mendicant immediately accosted them. The fellow was kindly and firmly told that from that day begging would be no longer permitted. A sergeant conducted the man to the Town Hall for registration. On that day 2,600 beggars were seized in Munich alone. Each apprehended person was released until the following day, when he was to report to the House of Industry—with the incentive of room and board to aid him in his resolve.

Rumford, created a Count as a partial reward for his services, was so successful with his gigantic administrative task that even the beggars respected him, and he enjoyed as well the support and confidence of the governing classes. Most of the vagabonds so softened under good treatment that they presented scarcely any problem to the city for a number of years. There was at no time a suggestion of mutiny, and the idol of orderliness, worshipped by the originator of the scheme, was so revered by the inmates that there was little friction. Harsh language and ill-treatment from the overseers was not permitted. Rumford himself remarked later that "not a blow had been given to a child, while thrift had so abundantly followed from it, that even extra rewards had been granted to the deserving." Such large quantities of goods were produced by the workers that they clothed the Bavarian troops, sold to the public at home and exported to foreign lands.

ORIGIN AND UTILIZATION OF DIATOMACEOUS PEAT DEPOSITS

By PAUL S. CONGER

RESEARCH ASSOCIATE, CARNEGIE INSTITUTION OF WASHINGTON; CUSTODIAN OF DIATOMS, UNITED STATES NATIONAL MUSEUM

SUPPOSE you had visions of some day building yourself a summer cottage, or of realizing nicely from the sale of shore property with gently sloping beaches, on a beautiful quiet lake in the northern woodlands. In the meantime the lake has mysteriously filled up with mud and with a luxurious growth of water weeds and grass, and is disdained by vacationists and fishermen alike, and accredited only by transient duck hunters. You would readily part with your holdings for a few dollars per acre to the first bidder; but withhold judgment, for perhaps this lake is worth more than your unfortunate outlook belies.

Leachings of the soil over thousands of years have supported plant and animal growth in all lakes. Their remains have gradually come to be deposited in the lake beds as vast quantities of organic peat, marl and other substances, which, returned to the land, have fertilizing values and properties of improving the texture and water-holding capacity of the soil. Under somewhat different conditions other lakes are laying down deposits of diatomaceous earth. This is a material of high commercial value for a wide variety of industrial uses, including insulation, filtration, polishing, absorption, etc. Looked at in this light, lake bottoms and marshes (the filled-in beds of old lakes) comprise some of our country's richest resources, and represent assorted and concentrated materials of untold value. With the application of practical and judicious methods for removing and reclaiming this wealth of material we shall still have our lakes, many of them improved and restored to their pristine beauty.

The diatomaceous deposits alone concern us here. That some marshes and lake bottoms may be sources of such material of great purity and high value is reputed to have been first realized when some wondering individual examined minutely the snow-white ash left as a residue of one of those subtle and devastating fires which sometimes get started in dry marshes. Such fires, ignited by adjacent forest fires, volcanic lava flows, lightning or various human agencies, once started in the dry, highly organic peat of old marshes, will smoulder along unnoticed deep underground for months, or even years, until all trace of combustible material has been consumed. These fires are aided by the air in the loose peat, by very inflammable marsh gases and by the momentum of their own accumulating heat. Then, if the muck consisted originally only of diatoms and organic plant remains, as certain of these lake sediments do, only diatom shells remain when the organic peaty material has burned off. These silica shells are very resistant and do not melt under a temperature of about 1,600 degrees Centigrade (2,800 degrees Fahrenheit), much beyond the temperature attained by such a slow-burning fire. We may well imagine the astonishment of the first observer to examine minutely this ash, on finding it to consist so purely of the shells of diatoms, sometimes to the extent of nearly 99 per cent.

Imitating the procedure of this acci-

dental discovery, a well-standardized method has grown up for processing such lake muds and peats of favorable composition in order to recover diatomaceous earth. Operations of this kind are being carried on in Florida, New York and New Hampshire in this country, in the maritime provinces of Canada and in other parts of the world. As is best shown in the accompanying photographs of various phases of this procedure at a Florida deposit where fine material is found, the muck is dug from shallow marshy bogs, either by hand or by dragging or pumping. Hauled by a small trackway to a plant on the shore, it is formed into cakes from which excess water is pressed by a hydraulic press. The pressed cakes are spread on racks to dry in the sun and air. They are very light in weight when dry and can be hauled in large truck loads to a central plant. Here the peat is burned, about a ton at a time, for several hours in a large incinerator, until all organic matter is burned off, leaving only the pure diatoms as a white cake. This is dumped into a large, slowly revolving tumbler, which gently breaks it up. A forced draft from this apparatus carries the dust consisting of single shells and fragments through a series of air-classifying or grading chambers, where by means of cyclonic air currents the finer particles are separated from the coarser, each grade being drawn off in bags at respective points along the line.

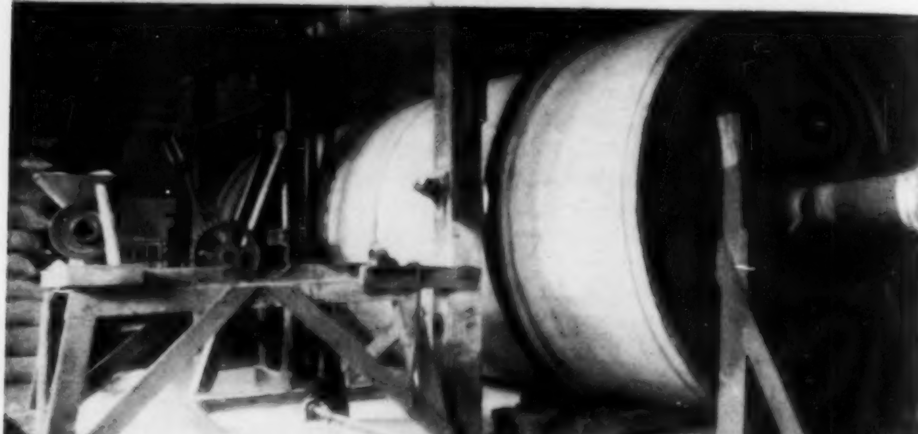
A question immediately arises—"Why resort to such an elaborate and expensive process, when mountainous deposits of very pure fossilized diatomaceous earth are to be found all through the western part of the country, clean, exposed and ready to use merely upon digging it up?" The merit of the former lies in the counter-balancing of its higher initial cost by its greater accessibility to eastern industrial markets, for diatomaceous earth is an extremely light and bulky material—a ton of it takes up a great deal of space—and the cost of shipping it long distances is often prohibitive. Then, too, the ignited bog material sometimes has superior qualities for certain purposes, for "diatomaceous earth" is no longer a specific term, but various earths are found to have widely different properties, depending largely upon the species of diatoms of which they are composed. The kinds comprising a given earth, as well as the purity of the material, depend largely upon the particular environment where the diatom growth and deposition have occurred. Thus a very close and direct association may be drawn between the industrial application and those ecological and limnological conditions under which an earth is produced, and it is with the understanding and importance of these relationships, rather than with the commercial value of lake peat, that this article is primarily concerned. It will be seen, however, that the commercial value of a deposit, its intrinsic purity and the scientific principles of its formation are all intimately related; hence it seems helpful to approach the purely scientific side of the subject from the standpoint of the industrial purity of diatomaceous sediments.

This whole study became motivated in a somewhat casual way as the result of the discovery of very concentrated diatomaceous sediments, while making general studies on diatoms in northern Wisconsin lakes during the summers 1936–38, at the Trout Lake Limnological Laboratory, upon the invitation of Dr.

Courtesy of the American Diatomite Corporation.

DIGGING DIATOMACEOUS PEAT

UPPER—THIS BLACK MUCK WHEN BURNED LEAVES A SNOW-WHITE POWDER OF OVER 98 PER CENT. DIATOMS. CENTER—TRACK FOR HAULING MUCK, OVER SHALLOW LAKE FORMED BY ITS REMOVAL. LOWER—PRESSING EXCESS WATER FROM MUCK WITH A HYDRAULIC PRESS.




AMERICAN DIATOMITE CORP.

Chancey Juday and Dr. E. A. Birge, and in cooperation with the University of Wisconsin and the Wisconsin Geological and Natural History Survey.

A chance collection of very rich diatomaceous mud from a small obscure lake immediately impressed the writer with its possibilities as a source of useful diatomaceous earth, and on further thought with its potentialities as a phase in the formation of fossil deposits. Certain conspicuous features of this lake were noted and they stimulated an interest in the subsequent examination of other lakes for similar materials. Further pursuit of the above suggested exploration led to the scientifically interesting and economically useful discovery that the lakes of this northern Wisconsin region represent diatomaceous deposition in all degrees of purity, from sediments containing practically no diatoms to others that are almost pure, with a relatively high proportion of lakes forming the more pure deposits. The super-abundance of fine accessible fossil earths in the West, with minor quantities in the East, and ample production of the burned peat product, had previously detracted from any thought of such occurrences in the central part of the country. In one fourth of the sixty-four lakes first examined, the material was considered sufficiently pure to be industrially important, and a number of others approached this in quality. In the best deposit located, the loose fluffy sediment lay but half a foot under the surface of several acres of open water, with some square miles of surrounding marsh land that may possibly overlie equally good sediment. A correspondent, Mr. S. M. Preston, of Detroit, describes the appearance of a similar diatomaceous bog in a way that seems worthy of mention here. He says, "With this material so thick in the lake to within a foot of the surface, it leaves a body of water (?) that is only a menace to life, human and animal." Such a lake contains no fish, nor little other life, and its soft but viscous mud is truly a treacherous mire to any animal that attempts to cross it or to any human that unhappily becomes involved. Its only use to man is as a source of the diatomaceous earth, the recovery of which has the dual benefit of affording a useful product, and clearing the lake of the above-mentioned hazard, suiting it better to human interests, and providing once more a favorable environment for fish and other life.

The muck of the best lake when dried yielded 73 per cent. silica, entirely in the form of diatom shells, and largely of a small uniform type, both of which mean a high-yielding and high-grade material. The additional substances consisted almost entirely of the organic matter residue of the diatoms themselves, which, when burned off, left only the useful shell portion as a fine white powder. In other lakes the muck contained a higher percentage of general plant remains, but yielded on incineration an equally concentrated diatomaceous material. Some other lakes in the region found to be depositing rich diatomaceous sediments are Allequash, Big, Big Arbor Vitae, Found, Grassy, Little Crooked, Little Rice, Lost Canoe, Madeline, Mann, Sweeney, Trout, Wildcat and Wolff. In some the material is localized in quiet protected parts of the lake, as in Trout Lake, and in others it occupies practically the entire bottom of the lake, as in Wildcat Lake. Most of these lake sediments lie under considerable depths of

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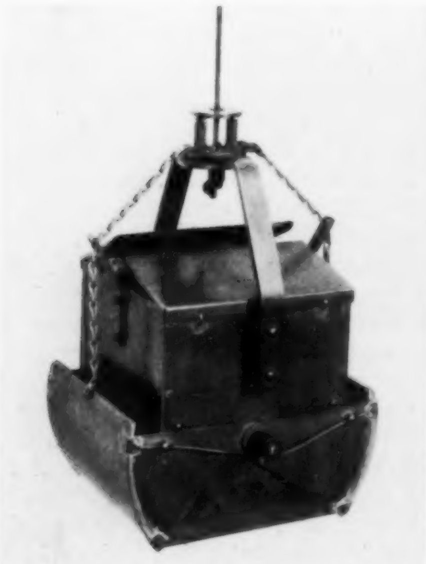
Courtesy of the American Diatomite Corporation.

PROCESSING THE PEAT TO OBTAIN DIATOMACEOUS EARTH

UPPER—PRESSED CAKES OF PEAT DRYING IN THE SUN. CENTER—REVOLVING TUMBLER FOR BREAKING UP LOOSE MASS OF INCINERATED PEAT. LOWER—REFINING PLANT WITH BAGS OF PURE DIATOMITE, READY FOR SHIPPING.



Courtesy of Dr. Chancey Juday.
CLAM-SHELL PEAT SAMPLER
EKMAN TYPE, WITH JAWS OPEN, READY TO LOWER

water, and consequently, in view of the large available quantities of the more accessible earth, must be looked upon as deposits of potential rather than immediate industrial value. Although only a small proportion of lakes in general conform to the strict conditions necessary to the formation of very pure material of this kind, the great number and variety of lakes in northern Wisconsin, relative to the few studied, suggest the likelihood of many such deposits as yet undiscovered in Wisconsin alone, with doubtless still others in Minnesota, Michigan, New York, New England, southern Canada and similar concentrated lake regions throughout the world. An additional benefit of these deposits to the northern lake territory is that of a welcome economic asset and added means of livelihood in a region that is climatically rigorous, agriculturally poor, deprived of its forest and otherwise generally deplete in natural resources. Reflecting upon previous rich collections from other lakes of similar type, the writer reexamined some of these and found several lakes on Cape Cod, and one in Maryland, producing such sediments. It is impossible to estimate the wealth of material which may thus be available and actively forming to-day.

Conditions of the Formation of Pure Diatomaceous Deposits

The profusion and great variety of lakes in the northern Wisconsin region, together with the high incidence of such deposits, suggested a study of the circumstances under which such pure deposition takes place, the exact conditions and underlying principles of which have apparently not been stated heretofore.

For this purpose the topographic and limnological features of the lakes were studied in connection with various tests on mud samples from the bottoms of the lakes. Such samples were collected with the little double-jawed, steam-shovel-like clam-shell dredge illustrated in the accompanying picture. This was lowered at the end of a line, with the jaws open, to sink into the soft mud. Then a small brass weight slipped down the line, released a trigger which allowed springs to snap the jaws shut enclosing a mud sample. Imitating, again, in the laboratory, the incineration treatment of such materials, this mud was dried, burned at several hundred degrees, examined microscopically and tested for iron, lime and other substances to determine its diatom purity.

The results of this study soon gave evidence of assuming a four-fold interest: (1) The limnological conditions necessary to this type of sedimentation. (2) A generalized and systematic basis for evaluating our lake deposits. (3) A series of criteria for prospecting and predicting further deposits. (4) Under-

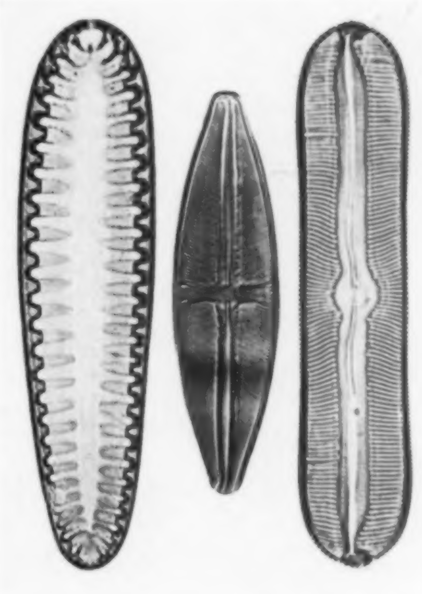
standing of the formation of our pure deposits of fossilized diatom earth.

To most of us lake bottom muds superficially look very similar, brownish-black and sticky, but examined as above it is little short of spectacular to see how different is their composition; scarcely two are alike. Although many sediments are a mixture of various materials, as might be expected, it is impressive to note how many lakes are forming quite pure deposits of one kind or another.

Nature is a great classifier and organizer. By the slow sorting of materials through differences in mass and gravity, by chemical segregation on a large scale (solution, precipitation and reaction) as the chemist does on a small scale in his laboratory, by the separation and elimination one after another of associated substances—by all these, nature achieves the accumulation of a certain material in one locality or stratum and of something else in another. So the great dynamic agencies in the molten lavas within the earth have brought about the orderly separation of useful minerals. Even the winds, and more especially the waters, of the earth, so frequently thought of as distributors instrumental in scattering substances far and wide, tend to operate also in bringing together like materials into an orderly grouping. Heterogeneous mixtures tend to separate into groups of homogeneous materials, and order comes from chaos.

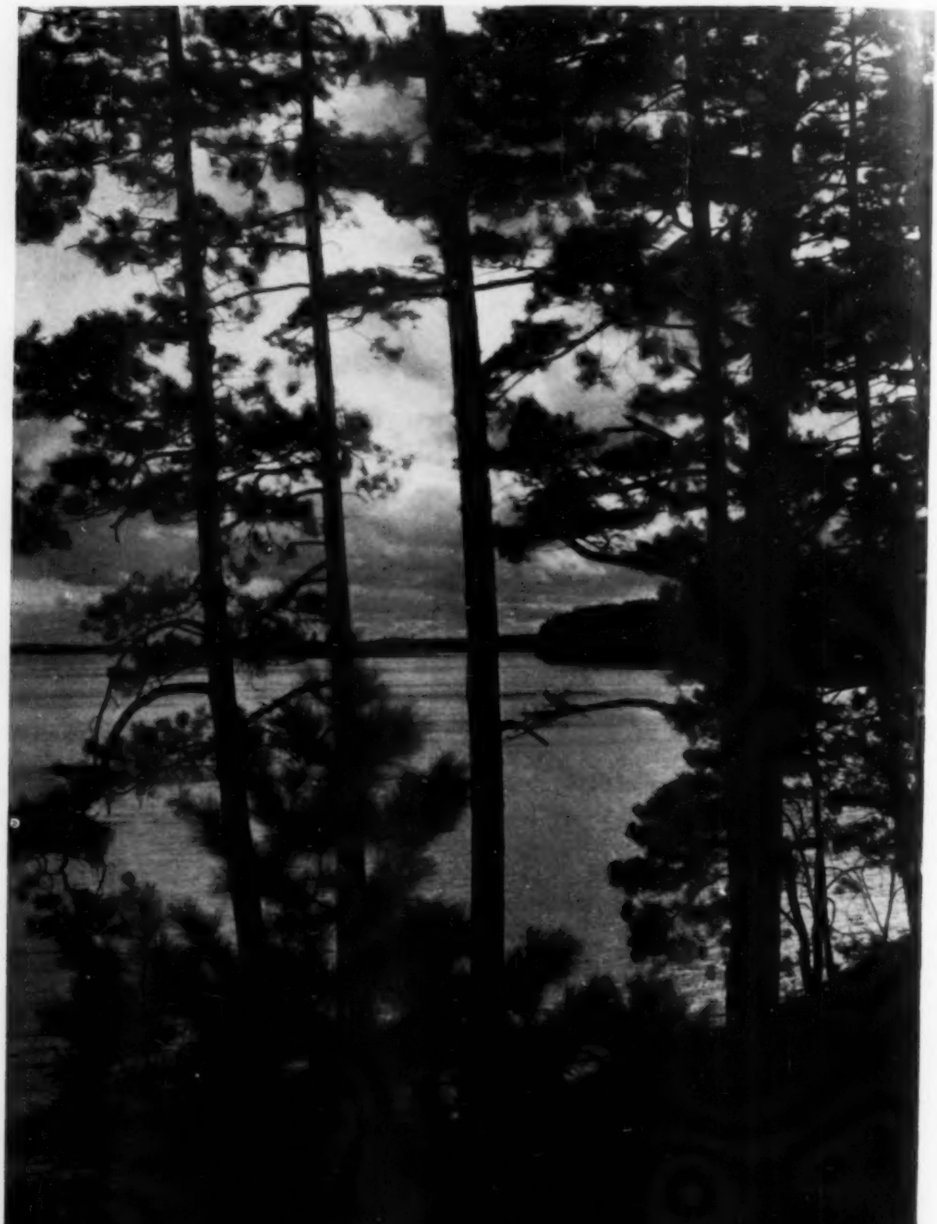
Thus one lake lays down a bed of highly calcareous marl, another accumulates an almost pure organic peat comprised of decaying plant remains, and still a third deposits only the siliceous shells of diatoms to produce a pure diatomaceous sediment. What, then, are the highly discriminating conditions of such pure deposition?

One can not but marvel at the formation of beds many feet in thickness, of a



TYPICAL DIATOMS FROM LAKE MUD
SHOWING THE FINE STRUCTURE ON WHICH USE FOR FILTRATION, ABRASION, ETC., DEPENDS. ×470.

single material such as diatom shells. These, accumulating at the very slow rate of perhaps no more than one-hundredth of an inch in a year, or less, would require thousands of years of uninterrupted deposition to form such thick beds. To attain the very high degree of purity exhibited by many beds of snow-white diatomaceous earth widely distributed in the western United States, and prevalent in many parts of the world, we must realize that, throughout these long periods of time, no significant change can have occurred, no outside material can have entered, to disturb the even tenor of this process. When we think of the strenuous forces of nature and the changing influences of civilization, it is hard to conceive of such long-continued periods of tranquil and unaltered sedimentation, free from intrusion of appreciable amounts of foreign materials due to dust storms or soil erosion.



Courtesy of Wisconsin Conservation Department.

TROUT LAKE, VILAS COUNTY, WISCONSIN

THE CENTER OF THIS LAKE HAS DIATOMACEOUS MUD AT 35 METERS DEPTH. THIS MUD IS SOFT AND GRAY WHEN DRY, AND CONTAINS 65 PER CENT. DIATOM SHELLS.

Indeed, it is quite probable that many lakes, which, free of these external factors, in the past, have laid down good deposits, may not continue to do so henceforth under the disturbing artificial conditions to which they are now subjected. Exceedingly small amounts of dust or eroded soil, for instance, may represent a considerable proportion of serious contamination when added to the very thin annual increment of diatom shells. In past ages, absence of cultivated areas and the presence of forest cover protected lakes from these intrusions. Only by the most stringent restrictions has nature controlled and maintained such purity of deposition over these vast periods of time. Time is a very important element.

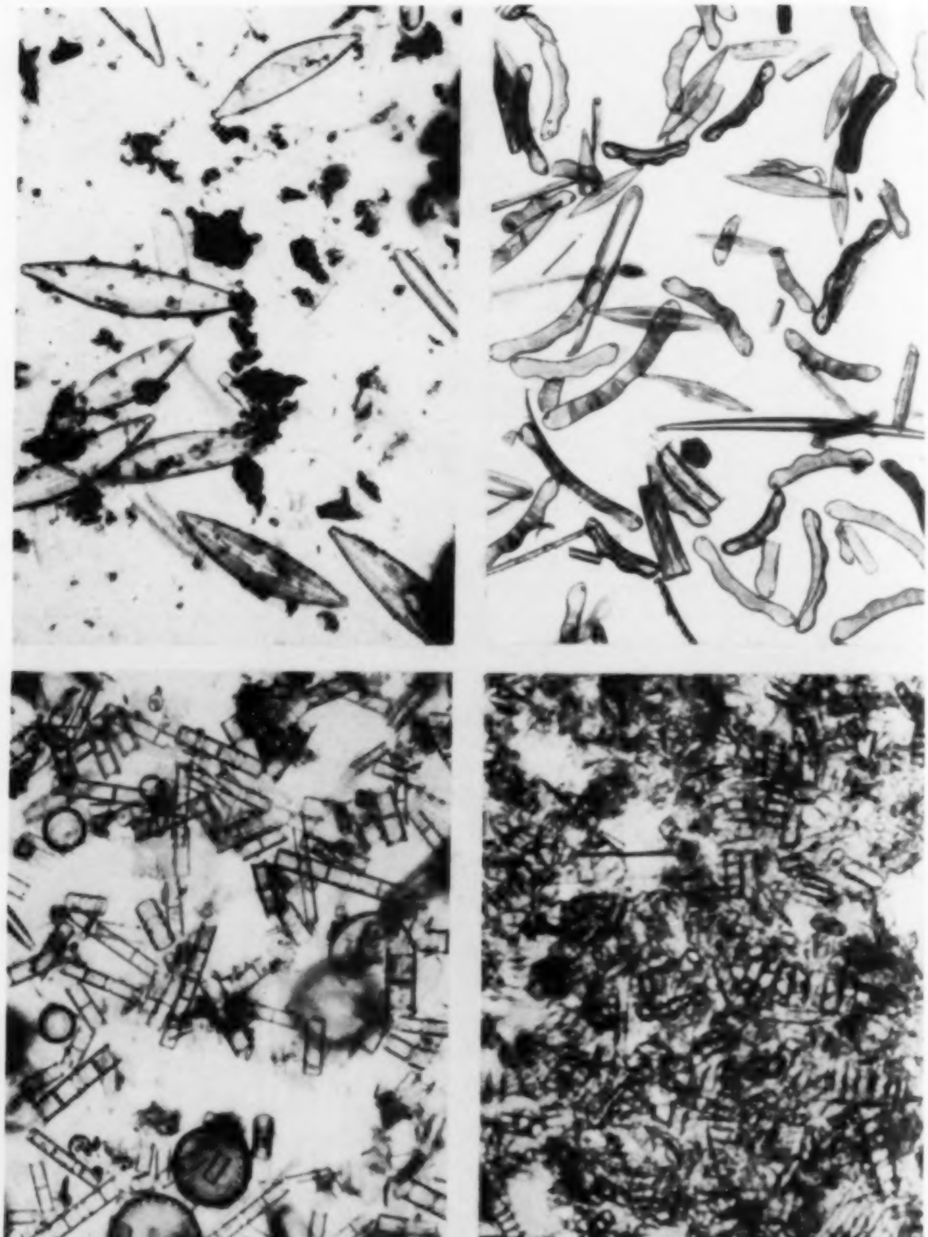
The limnological conditions requisite to the formation of pure diatomaceous sediments resolve themselves, *a priori*, into two general sets of factors: (1) those favorable to the abundant production of diatoms, and (2) those essential to the complete exclusion or elimination of all other materials. It is obvious that the presence of diatoms assures a rich diatomaceous sediment, providing all other substances are excluded or eliminated, and it is our hope here to see how this is nicely accomplished in many natural bodies of water by the beautifully adjusted association of favorable factors.

The positive condition of abundant production of diatoms is generally well satisfied and may be passed over quickly. Diatoms are found almost universally distributed in natural waters and often producing in great abundance. In these northern lakes conditions are very favorable to abundant production. The vital nutritive elements are present, with a goodly supply of dissolved silica of which the deposits are formed; the waters are cold, favoring diatoms in preference to other forms, keeping down bacteria and decomposition, and aiding solution of carbon dioxide and oxygen essential to diatoms; low decomposition and a small influx of basic elements tend toward neutral or slightly alkaline reaction favorable to diatom growth; the waters are generally clear, with good penetration of light.

It is rather the negative condition, that of exclusion of all other substances, that is more critical and less frequently satisfied. Such foreign and contaminating substances are best learned by comparison of pure with impure diatomaceous earths, and are found to be mainly of the following types: (1) Organic matter; (2) sand, silt and clay; (3) lime or magnesia deposits; (4) iron; (5) sponge spicules.

Organic matter is always present, if not as a contribution from other plant and animal remains, then purely by virtue of being a necessary constituent of the diatoms themselves. This is the case with the best bog material discovered in northern Wisconsin as described above, in which no extraneous plant remains were present, but all organic matter was that of the diatoms. Organic matter may be ignored as a serious or permanent contaminant, since it may easily be gotton rid of by burning off, and often it may even aid as a supplementary fuel in the burning process. In nature it tends to decompose and oxidize and to be ultimately removed by natural processes, leaving the pure white fossil earth with which we are more generally familiar.

Iron, likewise, is almost universally present as a constituent of the living plant or organism, and when persistent is detrimental to industrial use of the earth for many purposes. In many materials, however, it tends to be removed or transferred through the various agencies of bacterial action, utilization by further plant growth and ultimately by chemical reaction and



PHOTOMICROGRAPHS OF DIATOMITE FROM LAKE PEAT AFTER INCINERATION, SHOWING THE HIGH CONCENTRATION OF DIATOMS

UPPER LEFT—FROM OBSCURE AND UNNAMED LAKE NEAR ALDER LAKE, VILAS COUNTY, WISCONSIN. × 140. UPPER RIGHT—BOGGY MARSH, CLERMONT, FLORIDA. × 125. LOWER LEFT—BIG LAKE, VILAS COUNTY, WISCONSIN. × 160. LOWER RIGHT—SHALLOW HARD-WATER BOG, WISCONSIN. × 140.

reduction in the presence of organic matter.

The other contaminants above mentioned are not necessary constituents of diatom growth, and may or may not be present. When present they can not be eliminated by natural processes to eventually form pure earths, nor is it feasible to use industrially an earth containing any appreciable amounts of them or to get rid of them artifically. For the formation of pure diatom sediments their absolute exclusion is essential throughout entire duration of the long period of deposition.

Among these, sponge spicules are the least troublesome and are seldom of real importance. Very occasionally a layer with a high concentration of sponge spicules will be found. Sponges are sensitive and restricted to a slow and limited growth in a very narrow environment, their spicules are relatively heavy and not easily transportable; hence their contribution to most sediments is negligible.

Sand is rarely a factor in diatomaceous deposits. Because of its relatively much greater weight, water currents usually effect the deposition of sand and diatom shells in quite separate locations.

Elimination of the foregoing reduces our list of possible contaminating materials to lime, silt and clay, which are by far the most common and most troublesome sources of contamination.

Lime or marl is formed by lime-secreting plants or animals from calcareous matter in solution, brought in by inflowing drainage waters. When these waters do not drain from a limestone region and consequently do not carry calcium in solution, as is the case in many of the northern Wisconsin lakes, lime is naturally absent from the sediments. This is no more strikingly demonstrated than by comparing the northern lakes with Mendota and Oconomowoc Lakes, which lie in the limestone region in southern Wisconsin. In these latter lakes diatom production is, if anything, more prolific than in the nutrient-low northern lakes, but marl is also deposited, rendering the sediments correspondingly low in diatom content and economically worthless. Its exclusion is simple and complete under the proper drainage conditions as mentioned.

Neither so simple nor so certain is the complete exclusion of silt and clay. Having much the same relative density as the diatom shells, they are both difficult of exclusion and impossible to eliminate. These materials are almost universally distributed, and they are accessible to lakes through varied and changing agencies of influx, such as dust storms, soil erosion or dynamic disturbance of the lake basin itself. To prevent intrusion of these substances conditions must be such as to protect the lakes from their sources, and a study of many lakes has revealed the fact that physiographic and environmental features of lakes are chiefly instrumental in this respect. Thus small- to moderate-sized lakes surrounded by gentle hills and forest cover are protected from the sweep of high winds which may otherwise agitate the water sufficiently to stir up silt from the lake basin itself. Run-off and soil erosion are retarded by vegetation cover, and a surrounding forest minimizes the influx of air-blown detritus. Marginal growth of wild rice and other aquatics growing in shallow lakes is very effective in inhibiting agitation and transfer of sediments. In larger lakes, in central or deeper areas far enough removed from zones of water agitation to be protected from transported detritus, there may also be laid down very pure diatom sediments under conditions which would seem superficially quite unfavorable. This is the case with Trout Lake in Vilas County, Wisconsin.

The delicacy of adjustment of this whole set of conditions lies in the fact

Courtesy of Dr. Chancey Juday.
LAKE MARY, VILAS COUNTY, WISCONSIN
A TYPICAL HARD-WATER LAKE SUCH AS MAY DEPOSIT DIATOM SEDIMENTS. THIS TYPE OF LAKE FORMS PEAT CONTAINING A HIGH PROPORTION OF DIATOMS.

that while clay, silt and lime must be kept out, and iron avoided, an ample and continuous supply of silica in solution must be brought into the lake waters, for this is the material of which the diatomaceous sediments are built. Calcium and silica alike are brought into a lake in solution in drainage waters, utilized by organisms in building up their bodily structure and precipitated irreversibly when they die, as a deposit. The source of the silica is necessarily an external one, *i.e.*, the soils of the surrounding terrain, which, hence, must be siliceous, and free of lime. As has been said, when lime (or calcium) is abundant a marl deposit is formed, and it is only when lime is absent from the drainage area that a pure diatomaceous sediment is free to accumulate.

Clay and silt are almost invariably coincident with the source of silica, and the waters which bring in the silica in solution must not carry in particles of the former. This is achieved in several ways which are intimately associated with the physiographic features of the lake basin. Outstanding physiographic features of the region are the fact of glaciation and the presence of springs, and it will be interesting to see how these are associated with the formation of pure diatomaceous sediments.

Early in the investigation it was recognized that springs are very closely related to rich diatom production. Several conspicuously fine shallow water sediments were underlain by springs. To one's hand, the half a foot of water above the fluffy gray mud was very warm in the summer sun, but when the hand was plunged a half a foot below the surface of the muck an icy cold temperature was encountered.

Of the two general types of waters that feed a lake, surface inlets or run-off and springs or seepage waters, the latter are of distinct advantage in every respect, as may be seen by the following comparison:

Courtesy of Dr. Chancey Juday.

FORESTRY BOG, VILAS COUNTY, WISCONSIN

A TYPICAL SOFT-WATER ACID LAKE, PRODUCING DIATOMS, BUT LAYING DOWN DEPOSITS PROPORTIONATELY LARGE IN ORGANIC MATTER.

Study of the characteristics of a large number of springs indicated that while they contribute abundantly of dissolved silica, this contribution is made through the undisturbing addition of cold water (filtered free of silt, clay and detritus) to the bottom of the lake, bringing in no contamination. This is quite in contrast to the heavy load of silty material which inflowing streams gather from run-off and soil erosion, and often bring in from upland areas to spread out through the surface waters of a lake, whence it may sift down and contaminate all sediments. Spring and seepage waters filter slowly in intimate contact with the soils through which they pass, and numerous analyses of spring waters by Birge and Juday show that their dissolved silica content is several times as high as that of the lake waters which they feed.

Though springs are thus the ideal method of supplying silica and nutrient salts with the exclusion of all detritus, surface drainage waters may, under favorable circumstances, fulfill the same function, though never with the absolute discrimination of the former. Sluggish streams, filtered through growths of wild rice or higher aquatics about their mouths, may often be efficient in bringing in clean nutrient-bearing waters.

The passage of the ice sheets over this region has been either directly or indirectly responsible for many of the conditions favorable to formation of pure diatomaceous sediments. Glaciation has been of major importance in the following ways:

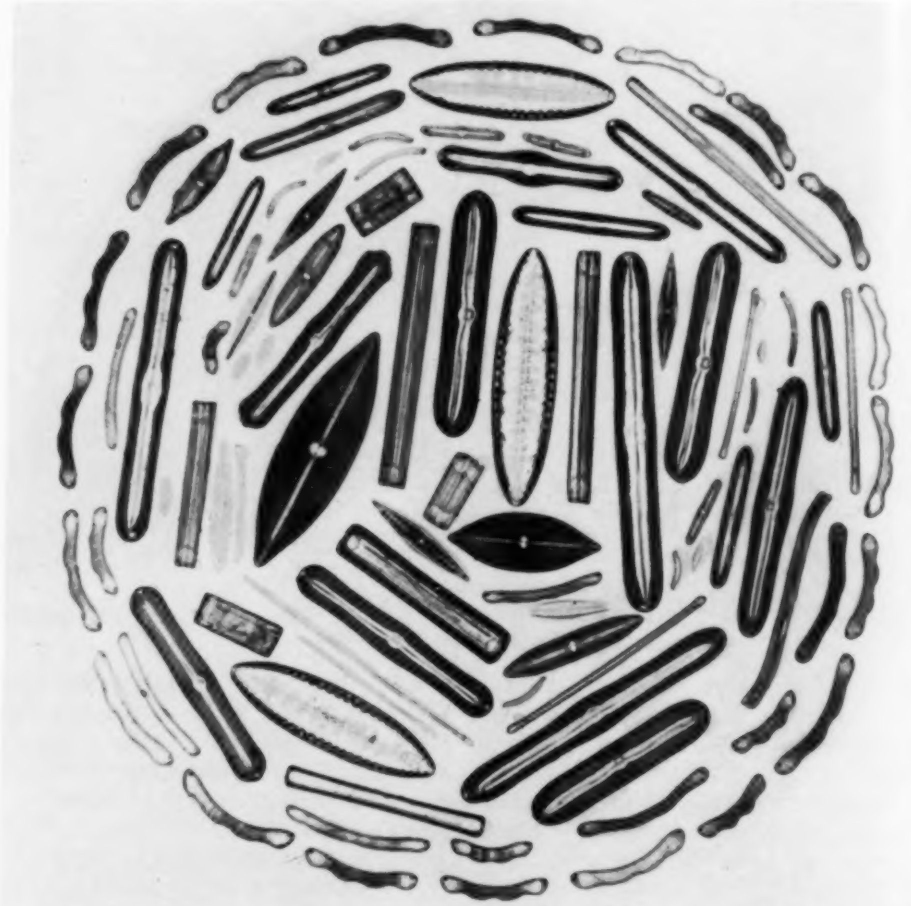
(1) Formation of innumerable lakes, which serve as places for production and deposition of diatoms.

(2) Arrangement of the topography in such an apparently disordered fashion as to inhibit development of large and highly erosive drainage systems.

(3) Formation of large numbers of seepage type, spring-fed lakes.

(4) Protection of lakes from wind erosion and water agitation by chaotically placed hills.

(5) Formation of lake basins from material consisting of ground igneous rocks and siliceous



SELECTED GROUP OF CHARACTERISTIC DIATOMS FROM A BOG PEAT. ×150.

sands transported from the north; with finer soils and lime washed out, this material peculiarly favors diatom production—silica is abundant, lime is scarce.

(6) Providing thus, by their sorting action, lake basins in a coarse-grained porous substrate, pervious to abundant springs and seepage waters; drainage systems have been inhibited, springs and seepage waters have been given advantage.

(7) With preference to seepage waters, the favorable conditions of springs are realized—cold waters, free of detritus, low in bacteria, neutral or slightly alkaline, feeding from the lake bottom with no disturbance.

Though glaciation has greatly enhanced the production of diatomaceous sediments in this region, as stated, it is by no means indispensible in such formations. Application of the same underlying principles indicates that identical results may be derived in a number of somewhat different ways, but following essentially the same analytical process by which nature sorts and separates these materials.

In Florida, not reached by the ice sheet, for instance, lakes abound in flat or slightly rolling country, their basins formed in siliceous sands overlying a hard coral sub-stratum. They are well

protected by wide stretches of flat or slightly rolling land covered with prolific vegetation, and drained by few or sluggish streams. Their bottoms are perforated by innumerable springs and fed by cold silica-bearing artesian waters, originating in higher regions of the coastal plain.

In Greenland and Alaska, and similar regions, cold waters from melting glacier fronts drain over igneous materials, to produce in the lower waters of quiet protected fiords a prolific growth of diatoms which settle to form pure deposits.

Likewise, small clean mountain streams in the West arising from melting snows and ice have brought into dammed-up valleys and crater lakes material suitable for production of many rich deposits.

All phases of the general subject of the conditions of pure diatomaceous deposition, as applied to both actively forming and fossil deposits, are being considered in detail in a monographic treatment now being prepared.

It is manifest that experience and familiarity with the principles of this process may aid in locating and recognizing lakes in which active deposition of this type is now going on. As a matter of fact one can stand on the shore of a lake and almost predict the presence or absence of such deposits. On the basis of the facts before us it is possible to formulate an ideal environment for the formation of such pure deposits, as that of a small to moderate-sized, rather shallow, cold, spring-fed, seepage-type lake, lying in a coarse siliceous-sand or rock basin, filled with reeds or marginal aquatic growth, and well protected by isolation in broad, flat, vegetation-covered country, or surrounded by forest-covered hills.

It is amazing that there are so many diatomaceous deposits of such very high purity, and yet, when we view the precision and constancy of these processes of nature it is perhaps equally amazing that there are not more of them.

CHANGES IN SHOSHONEAN INDIAN CULTURE

By Dr. JULIAN H. STEWARD

SENIOR ANTHROPOLOGIST, BUREAU OF AMERICAN ETHNOLOGY

When, in 1843, Colonel John Charles Frémont crossed the Rocky Mountains and entered the semi-arid, sage-covered deserts of the Far West, he wrote of the Indians: "From all that I heard and saw, I should say that humanity here appeared in its lowest form and in its most elementary state. Dispersed in single families; without firearms; eating seeds and insects; digging roots . . . such is the condition of the greater part." These Indians are now known as Western Shoshoni, Northern Paiute and Southern Paiute. They are divisions of the Shoshonean linguistic family which occupied the plateaus and Great Basin between the Wasatch Mountains in Utah and the Sierra Nevada and Cascade Ranges of California and Oregon.

Ethnographic study in recent years has confirmed the unanimous opinion of explorers, trappers and pioneers that the Shoshoneans were indeed impoverished. The greater part occupied a semi-starvation area where they subsisted upon seeds, roots, rabbits, gophers, snakes and even insects more than upon large game. Necessity compelled them to remain in small groups, single families often wandering about alone in search of food. When their slender resources failed, starvation was common and cannibalism not unknown. Their material arts and industries were simple. During most of the year they lived in crude, improvised shelters and windbreaks. Their clothing, if they wore any, was often made of sage bark or rabbit skins. By any standard, they were underprivileged.

But two groups of Shoshoneans were, upon the arrival of the white man in the West, living in a manner that contrasted sharply with the lowly condition of those just mentioned. The Northern Shoshoni of eastern Idaho and of western Wyoming were organized in large bands which traveled on horseback, hunted bison and fought their traditional enemies, the Blackfoot and Arapaho. Their fine appearance and military prowess commanded the respect of both white men and Indians. The Ute of eastern Utah and western Colorado, also members of the Shoshonean family, were similarly organized in well-mounted bands of hunters and warriors. Both tribes subsisted to a large extent upon bison, which they generally took east of the Rocky Mountains. They owned tipis, dressed in skin garments and lived with an elegance far more like that of the tribes of the Great Plains than of their own poverty-stricken relatives to the west.

This extraordinary difference between neighboring and closely related members of the Shoshonean family was not brought about by any native ineptitude on the part of the Western Shoshoni and Paiute nor by any special genius of the Northern Shoshoni and Ute. It was the result of an entirely understandable interaction of culture and environment, the broad outline of which can be traced for more than 1,000 years.

Three economic events are outstanding in Shoshonean history. First, they acquired the techniques and devices for procuring food that made life possible in this environment. Much later, a portion of them acquired horses from the Spaniards who had settled the Southwest and experienced fundamental changes in certain of their customs. Finally, modern civilization reached them. The profound effect of these economic changes, especially in shaping and delimiting their social and political pat-

terns, underlines the importance of human ecology among hunting and gathering peoples.

The main food resources of the Shoshonean environment are small, hard-shelled seeds and small game. Large game animals were so scarce that the population of any people whose subsistence was based primarily upon hunting must have been extremely sparse. The most effective exploitation of the seed resources under primitive conditions called for a knowledge of basket weaving and the manufacture of certain special forms for the different steps in gathering and preparing seeds. To procure rodents and other small game in important quantities, a knowledge of certain traps, nets and snares was necessary.

Of pre-basketry people in the Shoshonean area, archeology has revealed only the slightest traces. The archeological record really opens with the Basket Maker Indians, the predecessors of the Pueblo Indians, who occupied southern Utah and northern Arizona in the early centuries after Christ. To them must go the credit for solving the problem of subsistence in the desert, for they are known to have used all the essential hunting and gathering techniques employed by the modern Shoshoneans. They constructed large, conical baskets for gathering wild seeds, basketry trays for winnowing them and for parching them with live coals, flat stone slabs (metates) for grinding them and basketry bowls for boiling them. They even made tight baskets in which to carry water on their excursions into the deserts. They used long nets into which they drove rabbits and made snares and traps for catching smaller rodents. They learned to weave robes of twisted strips of rabbit fur and of bird skins and to make sandals of vegetable fibers. Without these techniques, life must have been extremely difficult in this country.

The Basket Maker Indians were not widely distributed through the West, but their entire economic complex, with the exception of maize farming, which they carried on in a small way, spread to the ancestors of the Shoshonean Indians who were then occupying the western portion of the Great Basin. Archeology of western Nevada provides the connecting links between the Basket Makers and Shoshoneans. A large cave contains stratified cultural deposits cov-

NEVADA SHOSHONI MAN, 1936.

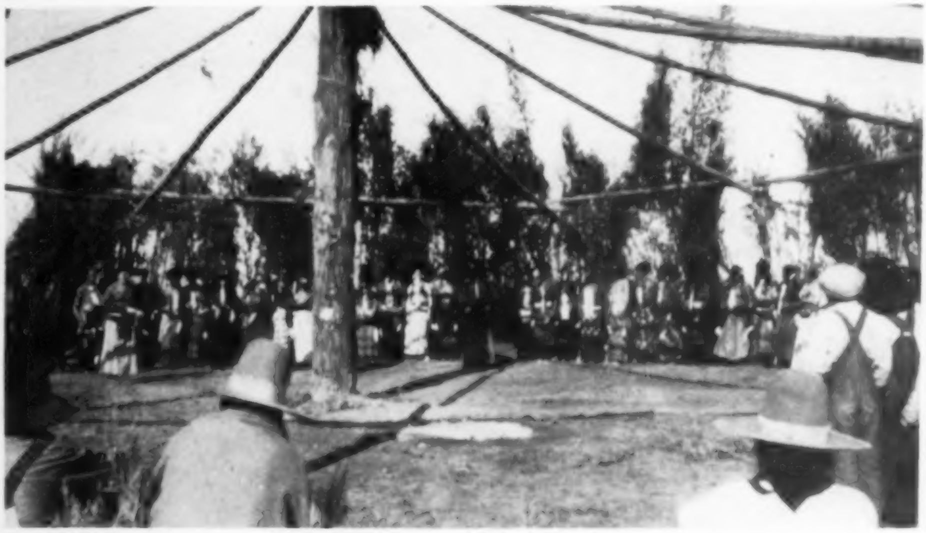
WESTERN SHOSHONI WOMAN, 1936.

TYPICAL SHOSHONEAN HABITAT.
SAGE-COVERED VALLEYS AND PINYON AND JUNIPER COVERED HILLS OF SNAKE VALLEY, NEVADA.

UINTAH UTE TEPEE IN NORTHEASTERN UTAH.
PHOTOGRAPHED BY HILLERS, POWELL EXPEDITION, 1873.

ering more than 1,000 years. Objects from the lowest stratum include hunting and gathering devices and clothing which are almost identical with those of the Basket Makers. Those from overlying strata, left during subsequent centuries, show slight readaptations of the economic complex, which, in the latest deposits, becomes specifically like that of the modern Paiute of this region.

The Shoshoneans, however, did not spread throughout the intermontane deserts until several centuries after acquiring the Basket Maker hunting and gathering techniques. The archeology of Utah and eastern Nevada shows not a trace of either Shoshoneans or Basket Makers. In fact, there is little evidence of any people until about 1,000 A.D., when this area became dotted with small villages of farmers who subsisted on maize and squash. This farm culture, including many features, such as house types and pottery, had sprung from that of the Pueblo Indians, who succeeded the Basket Makers in the Southwest. It had spread up the Colorado River and its tributaries and along the fertile piedmont of the Wasatch Mountains. But it did not endure long. After one or two centuries, the farmers were beset by trouble. Perhaps several factors conspired to their undoing, but one stands out. Warfare of some kind was forcing them to build their latest habitations in fortified and inaccessible locations. Possibly they fought with each other. More likely, new-comers to the area were at least partly involved. We know that a group of hunters entered the Great Salt Lake Basin at this time and took up residence in caves. The Pueblo Indians soon disappeared, and shortly thereafter the hunters also vanished. The fate of both peoples is a mystery, but it is certain that neither was related in any way to the Shoshoneans.



IDAHO SHOSHONI SUN DANCE, 1926.

The archeological record for the next 700 or 800 years is, except for western Nevada, largely a blank. There is no doubt, however, that during this time the Shoshoneans, whose artifacts and houses are of such a perishable nature that they ordinarily leave little archeological evidence, were spreading out into territory which they occupied at the opening of the historic period. The Northern Paiute spread throughout western Nevada and

MODERN CHIEF OF THE UINTAH UTE.

penetrated eastern California and southeastern Oregon. The Shoshoni came to occupy the territory from Death Valley, California, through central Nevada and southern Idaho to western Wyoming. The Comanche, who later moved to the southern Great Plains, probably formed a single group with the Wyoming Shoshoni. It is remarkable that the Comanche language to-day is almost identical with that of all Shoshoni, including even those of Death Valley. The Ute expanded throughout former Pueblo territory in most of Utah and western Colorado, while the Southern Paiute, whose language is very similar to that of the Ute, occupied southern Utah, southern Nevada and even some of northern Arizona and southern California.

Prior to the introduction of the horse to the eastern portion of this area, all Shoshonean culture was "low" or simple. Probably no primitive tribe in the world in recent centuries possessed fewer material goods and utensils nor more elementary social, political and religious customs. Isolated in their deserts from contacts with higher cultures after the Pueblo Indians were driven out, impoverished in material wealth and forced to subsist on a meager fare of rodents and sparsely growing seeds, their native condition gives a very vivid picture of human society devoid of elaborations and embellishments and stripped to an almost irreducible minimum. It does not, however, represent any "stage" of social development. Each group of human beings has had its own somewhat distinctive history. Although Shoshonean society shared certain basic features with all

ANCIENT TECHNIQUE OF FIRE MAKING DEMONSTRATED BY NORTHERN PAIUTE.

mankind, its special form was the result of having to support existence in certain environment by means of a specific economic complex.

As among all peoples, the molecule of Shoshonean society was the family. It consisted of the father, mother, children and perhaps grandparents and aunts and uncles. Sometimes a man had two wives. Sometimes, also, a woman had two husbands. But social and political ties transcending those of the family were infrequent and unstable. There were no clans, no close-knit bands, no true tribal units, and, in fact, no men who could properly be called chiefs—a state of affairs explained by the exacting nature of Shoshonean subsistence activities.

Shoshonean life was devoted almost exclusively to the unrelenting demands of the food quest. Vegetable foods provided the main staples. In early spring,

UINTAH UTE IN UTAH.
PHOTOGRAPH BY HILLERS ON THE POWELL EXPEDITION, 1873.

SOUTHERN PAIUTE WOMAN.
ON THE KAIBAB PLATEAU, NORTHERN ARIZONA, WITH CONICAL SEED BASKET. PHOTOGRAPH BY HILLERS, POWELL EXPEDITION, 1873.

when stored foods were exhausted and hunger was acute, each family left its winter encampment to forage through a country of perhaps 400 to 500 square miles. First, it sought greens in the mountains. Later, it wandered through the foothills or through the scorching and dry deserts to gather seeds, carrying water in pitch-coated basketry jugs. Persons who were too old or too infirm to travel were made comfortable, given water and such food as could be spared, and left behind to perish. While women gathered seeds and tended to their children, whom they were often compelled to carry on their backs along with the general baggage, men hunted mountain sheep, deer, antelope, rabbits and ro-

Webster McBride photo.

ERECTING THE CENTER POLE OF THE SUN DANCE LODGE, UINTAH UTE.

dents. Game was sought not only as a welcome ingredient in the pot of seed or root mush but as a source of skins for garments and other essential articles.

In the course of these wanderings, a family often encountered other families on a similar quest. But it was usually hazardous for them to remain together for more than a few days, because nature was so parsimonious in her distribution of seeds that few regions afford a supply ample for large numbers of persons. This explains why the early explorers usually met only single families or small groups of Shoshoneans, trekking wearily from place to place on foot and carrying

UINTAH UTE WARRIOR AND BRIDE.
PHOTOGRAPHED BY HILLERS, POWELL EXPEDITION, 1873.

MODERN ADAPTATION OF SHOSHONI BRUSH SHELTER.
FT. HALL RESERVATION, IDAHO, 1936.

their entire household equipment on their backs.

In the fall, however, nature was usually somewhat more bountiful when the nuts of the pinyon (*Pinus monophylla*) ripened. This nut was the most important species of all Shoshonean foods throughout the greater part of Utah and Nevada. Where harvests were good, large groups of people foregathered to dance, gamble and visit with friends and relatives whom they had seen rarely if at all during the remainder of the year. But these activities lasted only a few weeks. The harvested nuts had to be carried to a locality with firewood and water suitable for a winter residence. Here they erected a pole and brush lodge

PAIUTE BRUSH HOUSE.
ADAPTATION BY MODERN NORTHERN PAIUTE IN EASTERN CALIFORNIA OF ANCIENT SUMMER HOUSE.

SOUTHERN PAIUTE WITH BOW AND ARROWS.
NEAR LAS VEGAS, NEVADA. PHOTOGRAPH BY HILLERS IN 1873.

and stored the seeds nearby. If the pine nut yield had been good, they lived in comparative comfort during the winter; if not, many of the old and infirm, weakened by hunger, died.

People preferred to winter always in the same locality, which they considered home and where they might be near a dozen or more families of friends and relatives. Often, however, good crops of seeds, especially of pinyon nuts, occurred in very unpredictable localities from year to year. If a good crop were far from home, a family had no choice but to travel to that locality and make its winter home near the seed supply. This erratic occurrence of seeds, more than any other factor, prevented the formation of permanent associations and allegiances between Shoshonean families.

When gathering seeds, there was no way in which several women could cooperate to increase their production. In fact, each woman was likely to procure less if too many women worked in the same seed patch. Hunting, however, was different. A group of men hunting cooperatively could take several times as

SEPARATING THE CHAFF FROM SEEDS.
NEVADA SHOSHONI WOMAN USING THE WINNOWING BASKET.

much game as an individual hunter. Consequently, when enough men happened to be in the same vicinity and when game was sufficiently abundant, men joined in communal drives and shared the kill. Drives, however, were rarely profitable for more than a few days or a few weeks.

The most important drives were for antelope and rabbits. Antelope drives were under the charge of antelope shamans or "doctors," whose supernatural power was believed to be indispensable to the success of the drive. First, however, as an essentially practical device, the shaman directed the construction of a corral of juniper poles, having a gate to which two long fences converged. When this was ready and when antelope were known to be in the vicinity, the shaman undertook to render them docile and stupid by means of his power. Through singing and other measures, he captured the animals' souls, whereupon, bereft of their sense, they wandered helplessly—though usually encouraged by hunters from behind—into the corral where they were killed. Deer were sometimes also captured in drives aided by the shaman, though more often they were hunted in

SOUTHERN PAIUTE SUMMER SHELTER
IN SOUTHWESTERN UTAH. PHOTOGRAPHED BY HILLERS, POWELL EXPEDITION, 1873.

a purely practical way. Rabbit drives were always a lay business. Several long, low nets (identical with specimens found in Basket Maker caves) were placed end to end in a huge semi-circle. A crowd of people then beat the brush, driving the animals before them into the nets and clubbing them to death. Along certain rivers, especially in the Snake River in southern Idaho, families sometimes cooperated in communal fishing enterprises.

ANCIENT TYPE OF BRUSH LODGE.
USED BY MODERN SHOSHONI FOR A DOG HOUSE. FORT HALL RESERVATION, 1936.

Communal pursuits, however, were too short-lived to take up the slack in Shoshonean society. Husbands and wives always remained together, carrying on their respective and complementary economic tasks and caring for their children. But allegiances between families were transitory. Pinyon nut harvests, communal hunts and occasional brief fiestas or dances during periods of unusual abundance of certain foods were the only affairs which were cooperative. The same families did not always participate in these. It could not have been otherwise so long as Shoshonean subsistence was limited to hunting and gathering with the few technical aids—baskets, grinding stones, bows and arrows, traps and nets—at their command.

The Northern Shoshoni and Ute had already had the horse for many years when first visited by the white man and exhibited a very different state of affairs. The exact date of the introduction of the horse is not known, but there is no question that it came originally from the Spaniards who had settled the Southwest. About 1730, Wyoming Shoshoni warriors, having the advantage of being mounted, routed their Blackfoot foe, who had not yet acquired horses. In 1806, Lewis and Clark saw many horses among Shoshoni on the Lemhi River in Idaho. Horses were probably transmitted from the Southwest through the Ute Indians of Colorado and Utah who, at Escalante's visit in 1776, seem to have possessed them. Thus, by the early part of the nineteenth century, when trappers and explorers began to open up Shoshoni and Ute territory, horses were fairly numer-

ous. They had not, however, spread into Western Shoshoni and Paiute territory because the grasslands are too limited in the Western deserts.

We have no eye-witness account, of course, of what the Northern Shoshoni and Ute were like before the introduction of the horse. Very likely the Wyoming Shoshoni, who lived in bison country east of the continental divide, were much like other Plains tribes. The other Shoshoni and Ute, however, must have been very similar to their kin to the west.

The story of the horse in the western Great Plains has often been told. It wrought important changes in Plains Indian culture, but these were in the direction of intensification of pre-existing patterns rather than innovation. It facilitated bison hunting, increased warfare and generally heightened the tempo of all activities. Introduction of the horse to the Shoshoneans completely revolutionized certain fundamental patterns. It opened entirely new possibilities for food getting, laying a foundation for social and political forms which had previously been impossible. It brought cultural contacts which resulted in the acquisition of many new customs. And it was responsible for clashes with Plains tribes which implanted a militaristic spirit.

While having to travel on foot in pre-horse days, the Northern Shoshoni and Ute were no doubt essentially seed gatherers, living in small groups like their relatives to the west. Some bison occurred in both Idaho and Utah, but they were limited in number and became extinct at an early date. The introduction of the horse freed these Shoshoneans from the necessity of wandering tediously each year through a restricted terrain in search of vegetable foods and assured them an ample supply of meat. Communal hunts on horseback were vastly more efficient than drives on foot. Moreover, it was now possible to travel into country where game was far more numerous than at home. The earliest records show that seasonally the Ute and Shoshoni left their deserts and crossed the Rocky Mountains to hunt the great bison herds on the high plains. The Wyoming Shoshoni were, of course, better situated, having no great distance to travel.

But the horse had another and more important effect upon social groups. The number of people who can live together in the same community depends upon their ability to concentrate their foods at a central point. So long as they must transport everything on their own backs, they are more likely to settle near their foods than to attempt to carry their foods 25 or 50 miles to a central village. The horse solved the transportation problem. Bison meat and, in fact, such other foods as seeds, berries, roots and fish were

WESTERN SHOSHONI WOMAN,
WEAVING BASKETRY BOWL, 1931. STIMULATED BY CONTACTS WITH CIVILIZATION, THE BASKETRY ART HAS IMPROVED AMONG SHOSHONI IN THE REGION OF DEATH VALLEY.

A DEMONSTRATION NATIVE DANCE.
A MODERN PAIUTE MAN OF EASTERN CALIFORNIA.

transported by horse to large, central encampments where several hundred people wintered together. Many Idaho Shoshoni, for example, often traveled hundreds of miles into Wyoming to hunt bison or to western Idaho to trade bison skins for salmon and then returned to the vicinity of Fort Hall to spend the winter.

But this new freedom and security from starvation also carried a penalty. Hunting in the Great Plains brought the Shoshoni into conflict with the Blackfoot and, during certain periods, with the Crow Indians. In fact, the Wyoming Shoshoni had been enemies of the Blackfoot in pre-horse days. The strife was occasioned not so much by competition for hunting land as by a fundamental love of warfare which had infected many of the Plains tribes. War parties set forth to gain honors by counting coup, taking scalps and stealing horses. The Shoshoni were never safe during their bison hunts. But they too succumbed to the lure of warfare, and their own young men set forth on war parties often for the sole purpose of achieving distinction. If things became too hot on the Plains, they retired to the comparative safety of their deserts, where the Blackfoot raiding parties seldom dared carry the fight.

Warfare furthered the social and political cohesion which the horse and bison hunting had made possible. Large groups of families not only set forth on hunting trips together because of the advantages of communal efforts, but remained together for protection against raids. As these activities required some kind of supervision, certain leaders rose to great prominence. In short, previously scattered and independent families became amalgamated into bands under chieftains.

The bands, however, were never permanent, and the authority of the chiefs was neither absolute nor hereditary. Instead, influential men attracted a following, the size and permanency of which was extremely variable. Some wielded enormous power, like Chief Washakie of the Wind River Shoshoni in Wyoming, whose influence controlled not only his own people but extended into Idaho and Utah. Chief Ouray similarly commanded the respect of a large portion of the Ute. Other men often gained a con-

siderable temporary following only to have it disintegrate into a number of small bands.

In addition to bringing about this development of band organization among Northern Shoshoni and Ute, the horse facilitated the introduction of many new customs. Having greater material wealth, especially in bison skins, and better means of transportation, people largely abandoned pole and brush houses for skin tipis. They ceased to make sage-bark shirts and rabbit-skin blankets and wore complete skin shirts, leggings, dresses and moccasins, all modeled on Plains styles. They largely abandoned their basketry and made bags and containers of rawhide like those of their neighbors on the Plains. And they learned the manufacture of shields, spears, clubs and other war paraphernalia and adopted the elaborate system of war honors and ritual of the Plains Indians. More recently, they even instituted the Sun Dance, a typical Plains performance.

Meanwhile, the Western Shoshoni and Paiute remained at a primitive level. The Southern Paiute adopted a small amount of horticulture from the Pueblo Indians, but it never became an important factor in their economy. When the white man arrived, they stole his horses, but instead of using them as the Northern Shoshoni and Ute had done, they ate them. The horse, in fact, never became important to the Western Shoshoni and Paiute because their territory was deficient in grazing lands. Instead of expediting hunting in this area where there was little to hunt, horses would merely have eaten the very seeds and grasses upon which people relied.

The Western Shoshoni and Paiute remained substantially unchanged until nearly 1860. By this time, immigrants had taken up their best food lands and shot their game. Live stock, ranging widely over the country, had seriously reduced the quantities of wild seeds. Suffering acutely from food shortage, the Indians attempted to drive the white man out. Equipped now with a few horses, people, who had previously moved about independently, rallied under war leaders, and fighting broke out in various places in Nevada, Utah, eastern Oregon and Idaho. But these struggles had no chance of success and within a few years were subdued, the Shoshoneans' native period now at an end. Since that time, they have either attached themselves in small groups to ranches or towns in their former territory or have moved to reservations. Absorption of the white man's customs has advanced rapidly because it has been essentially a process of adding to rather than replacing native customs. Little to-day remains of aboriginal life except in the memories of the old people.

THEORIES OF FORMATION OF ORE DEPOSITS

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MANY of the early speculations concerning the origin of ore deposits contain hardly the slightest element of truth and are so enmeshed with astrological theories or colored by religious concepts as to be of no significance in a scientific discussion, however illuminating they may be as a record of the development of the human mind from lethargy to credulous activity and finally to critical alertness. For this reason and also to bring our discussion within the allotted pages it will be necessary to neglect historical backgrounds and to attempt simply to picture in broad strokes the present concepts concerning the origin of ore deposits. This picture, though drawn mainly for the reader unfamiliar with geology, may be of interest also to some geologists as emphasizing the intimate dependence of applied geology upon what we are pleased to call pure geology.

Although in this discussion we shall construct a classification of ore deposits it is wholesome to remember at the outset that however fond we may be of subdividing our knowledge into classes and constructing definitions of the classes these are merely devices for our own convenience, concessions to our ignorance, tricks to simplify our thinking. They are pedagogical misrepresentations of nature's ways, forgivable and useful in the limited state of our powers but having no counterpart in nature herself whose dominant notes are unity and integration, not division and isolation.

Although we commonly think of an ore as different from a rock in the sense in which "rock" is usually used, actually all ores are rocks and the boundary between them is drawn not by the geologist but by the business man at the commercial limit of profitable exploitation. A cheaper method of mining or treating or transporting nature's metal-bearing materials may shift a common rock into the category of an ore. The general trend of improved technology has been to make possible the use of lower and lower grade materials. It is customary and convenient to restrict the term ore to rocks that contain the metals or their compounds in workable amounts and we shall concern ourselves here only with ores in this sense. Many *non-metallic* elements and their compounds also find commercial application and some of them have been formed by processes similar to those involved in ore formation. Occasionally some uncritical writer jumps the terminology fence and refers to some deposits of the non-metals as ores, such as graphite "ores" or fluorspar "ores."

What seem to-day to be sound concepts of the origin of ores waited for their development upon the laying of a firm foundation of knowledge of the processes by which the commoner varieties of rocks have been formed. In particular there was necessary the clear recognition of the two great processes by which rocks are formed, namely, vulcanism and sedimentation, and the defining of the criteria by which the *igneous* rocks formed by the processes of vulcanism could be distinguished from the sedimentary rocks. So long as great bodies of igneous rock were misinterpreted as deposits laid down on the ocean's floor, as commonly happened up to the beginning of the 19th century, little progress was possible in the interpretation of ore formation, for upon this distinction hinges the subdivision of ore deposits into their two main categories.

Although we have stressed the fact

that ores are distinguished from the common rocks by their larger metal content, this statement if left unqualified would give too simple a concept of their relationships. It must also be understood that ores are a subordinate and very exceptional variety of rock constituting only a small fraction of one per cent. of the total body of rock that makes up the earth's surface. This is readily realized when we recall that large areas of the earth's surface, some of them half a continent in extent, are devoid of any ore deposits. This is true, for example, of most of northern Africa and of the interior of Australia. Obviously the formation of ores is very much less common than the formation of the common rocks and tends to be localized in certain regions.

A second point of great significance is that as a rule the metal content of the common rocks is extremely small as compared with the metal content of even our lowest grade ores. Thus it has been estimated that the average amount of copper in the common igneous rocks is about .01 per cent. whereas 1 per cent. may be taken roughly as the minimum amount in workable copper deposits, a ratio of 1 to 100. In the case of most other metals the contrast would be even more striking. There is, therefore, a sharp jump in the metal content in passing from the common rocks to those rare rocks that we call ores. These two facts, the relative variety of the ores and their relatively high metal content, clearly show that in the formation of ores some process of natural concentration has been operative, converting, in restricted areas, materials poor in metals into small but rich ore deposits.

From what has been said the reader will surmise that our present knowledge of the processes of ore formation has been acquired *pari passu* with our knowledge of the processes by which the common rocks have been formed and later modified. Almost every process by which the common rocks may be formed or modified finds its counterpart in some process of ore formation, and a list of the processes of ore formation becomes virtually a classification of all geologic processes.

It becomes evident, therefore, that ores may be formed by many and very different processes, and the situation is further complicated by the fact that several of these processes may cooperate, simultaneously or in turn, in the formation of a single ore deposit. In the following pages we shall try to analyze this seemingly complex situation into its simple elements.

What is the nature of those natural processes of concentration by which ores have been formed? The first great group of processes that may produce such concentrations are those associated with the attack of the air and of the waters of surface origin upon the rocks. The realm of action of these processes is widespread, being indeed coextensive with the land surface, but of shallow depth, being restricted to the few hundreds of feet to which the air and surface waters can penetrate the cracks and pores of the rocks in significant amounts. The effect of these processes is to wear down, or "degrade," certain parts of the land surface, but the material thus worn away must obviously be deposited elsewhere to build up, or "aggrade," other parts of the land surface or the bed of the ocean. The entire process, first degradation and then aggradation, is termed by the geologist "gradation." The first great class of ore deposits, and by and large the class most easily recognized and understood, is the deposits formed by gradational processes.

Ore Deposits Formed by Gradational Processes

The various ways in which ores may be formed at or near the surface by processes of gradation may be most readily

understood if a few representative instances are cited. In the Mayari and Moa districts in eastern Cuba large areas are underlain by a common igneous rock that contains only between 5 and 10 per cent. of iron, far too small a percentage to be profitably worked. This iron is mainly in chemical combination with silica and alumina. Surface waters and the gases of the air have, however, waged a constant attack upon this rock and in the course of long periods of years in this semi-tropical climate they have eventually produced about 15 feet of an incoherent soil that now contains around 50 per cent. of iron no longer combined with silica and alumina but with oxygen and water and constituting a valuable iron ore that has been shipped to Baltimore for smelting. The valueless components of the original rock were in the main carried away in solution, but the difficultly soluble iron oxides remained as a residuum to form what is known as a "residual" ore. While residual ores are one of the subordinate varieties of iron ores, essentially all the ores of the important metal aluminum are residual. It follows from their mode of formation that residual ore deposits are apt to be thin but their lateral extent may be considerable.

Seldom if ever does it happen that all of the valuable metal or its compounds concentrated as a residuum during the soil-making or "weathering" process remains in its original locality. Some is almost certain to be carried downhill by the run-off of surface waters and be deposited some distance away, usually in admixture with materials from other sources. In this way were formed the "placer" deposits that in past years have been one of the world's great sources of gold and that to-day yield a large fraction of the world's platinum and most of the world's tin. The formation of most placer deposits involves, however, more than the mere movement of the residuum of rock decay to a new locality; it involves a further concentration of the valuable component during this transport. In the case of gold, platinum and tin deposits these are the heaviest components and offer more resistance to transportation in streams than the lighter components. In the placers of Colombia in South America gold and platinum, each from different sources, are now mingled in the same gravels. Since placers are sediments they constitute one variety of sedimentary ore deposit.

In the degradation of the land surface, compounds of the valuable metals contained in the common rocks or in ores exposed to weathering are not always resistant to the solvent action of surface waters but may be partly or completely dissolved. Once in solution the metals may be transported with facility for distances measured in a few feet or in many miles. Iron in some of its combinations, such as the carbonates, is readily taken into solution in the soils and may be transported laterally for long distances to some lake or an arm of the ocean there to be reprecipitated as a sediment rich enough in iron to constitute an ore. The largest iron ore deposits of England, the famous Cleveland ores, are iron carbonate beds originating in such a manner. Such deposits constitute still another type of sedimentary ores.

Iron carried to the sea either in true solution or in very fine mechanical suspension (colloidal) may also be reprecipitated as the oxide hematite, and some of the largest of the world's iron ore deposits, such as those of Lorraine in France, of Newfoundland and of Birmingham, Alabama, were formed in this way. Their sedimentary origin is amply attested by the presence in the ore of features such as bedding, cross-bedding and fossil remains of marine origin, features common in the more ordinary kinds of marine sediments. The precise means by which the iron oxides were

deposited on the floors of the ancient oceans is still far from clear, largely because deposits of this sort for some unexplained reason are not forming in the seas to-day.

Before concluding our consideration of the ore deposits that owe their formation to the processes of gradation, mention must be made of some in the formation of which more than one gradational process has been involved. In the development of the greatest of the iron ore deposits of the United States, those of the Lake Superior region, there was involved first the deposition of iron-rich sediments in an ancient ocean, then at a much later period when these sediments had become part of the land surface their iron content was in places approximately doubled by the leaching out of components other than iron, that is by residual concentration.

Furthermore, gradational processes of concentration are often superimposed upon the processes of concentration related to vulcanism which are next to be described. Thus, for example, many of the great copper deposits formed in the first instance by solutions rising from volcanic sources have later been notably changed when exposed at the surface and subjected to oxidation by air and to the solvent action of surface waters. Copper has been dissolved from the portions of the deposits nearest the surface, carried downward in solution, and redeposited deeper down within the ore body. To this process, which is known as "downward enrichment," many of the world's copper deposits owe their extraordinary richness. Others owe their workability to this process which raised their tenor from below to above a workable grade. The largest of the copper mines of the United States, that of the Utah Copper Company of Bingham Canyon, is an instance of this sort.

Thus it becomes evident that the familiar agencies that are operative to-day in sculpturing the landscape—air, the surface streams, to a lesser degree underground waters, the lakes and the oceans—have been responsible in the past for the formation of many of the world's ore deposits, among them some of the largest and richest.

Ore Deposits Related to Vulcanism

There remains, however, a great group of ore deposits, including most of the ores of copper, lead and zinc, silver, tin and mercury and the gold ores other than placers, about whose origin many uncertainties have existed. The mineral veins, those sheet-like or tabular ore deposits following fractures in the common rocks, are the commonest, though not the only, form of deposit belonging to this group. One reason for uncertainty concerning their origin is not far to seek and is implied by the simple fact that no one has ever seen a metalliferous vein in process of formation. The conclusion to be drawn from this is not that mining geologists have been particularly unobservant but rather that the processes of metalliferous vein formation take place exclusively far below the surface where they are effectively screened from all possible human observation. Only long after, often millions of years after, these veins were formed are they finally exposed to our eyes and brought within range of mining operation by the slow wearing down of the surface by the process of degradation. The metalliferous veins are therefore presented to our view fully formed and whatever we learn of the processes by which they were brought into being must be a matter of inference rather than direct observation. Such handicaps serve rather to intrigue the geologist than to discourage him, and logical inference on the basis of careful observation may be a powerful weapon for discovery of the truth. Let us marshall briefly some of the observations and

inferences that have cleared away many though not all of the mysteries that have surrounded these ore deposits.

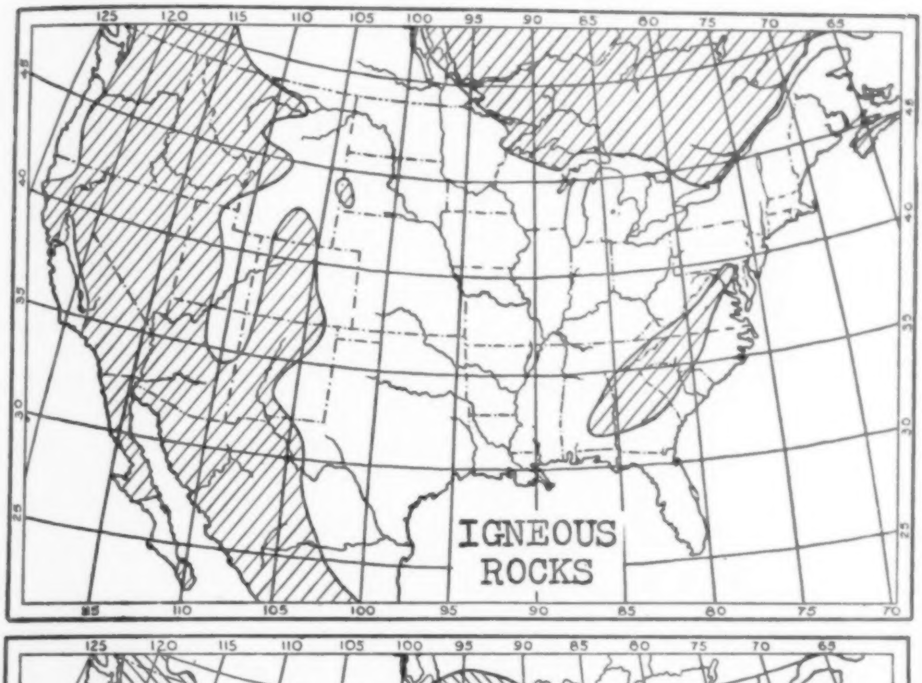
Excluding for the moment all those ore deposits that can be shown to have developed by the processes of gradation and centering our attention on other types, several broad relationships are of particular significance. First and foremost is the fact that regions characterized by ores of these sorts are also in general characterized by an abundance of igneous rocks. In short, there is a geographic parallelism between the distribution of ores and of igneous rocks. This parallelism is strikingly brought out for North America in the accompanying chart. The relationship is too general a one to be fortuitous. There is, moreover, a second broad relation that is almost equally significant, namely that the periods in the geologic past that were periods of ore deposition were also periods of igneous activity. The combined import of these two relationships is that ore formation of the sort now under consideration is in some way related to igneous activity, that is, to vulcanism in the broadest meaning of that term.

Vulcanism, however, is a process that is going on to-day at the surface of the earth, only locally to be sure, but often with a spectacular violence that has aroused not only the interest and awe of the layman, but inspired the searching investigation of the scientist as well. The processes of vulcanism as displayed at the earth's surface are now known in a wealth of detail and are well understood. Why then, if some ore deposition is a phase of vulcanism, is there any uncertainty concerning the ore-forming processes? The answer lies in the fact that ore deposition is not connected with those processes of vulcanism which are observable at the surface but with deep-seated vulcanism that can not be studied in action.

The relations between igneous rocks and ore deposits if viewed on a more restricted scale often confirm in an interesting way the evidence from the broad relationships. The tin, copper and other ores of the famous Cornwall district in Britain are closely associated with great bodies of granite whose coarse to medium textures show that they solidified a considerable distance below the surface. Away from the granites mineralization disappears. The great Braden copper mine in Chile and the famous gold deposits of Cripple Creek in Colorado are strictly localized in and around the "roots" of old volcanoes that have been laid bare by erosion. Similar instances could be multiplied almost indefinitely.

When consideration is narrowed to individual ore deposits additional evidences of a relation to igneous activity are revealed and a surprising variety is found not only in the metals involved but in the manner of their association with the igneous rocks. Because of such differences in association several classes of ore deposits may be recognized, each related to vulcanism but each formed by a little different mechanism of natural concentration of the metals.

In the first class are those ore deposits that are themselves igneous rocks and show clear evidence by the kinds of minerals they contain and the way in which they are intergrown of direct crystallization from molten rock material—or so-called "magma." Many of these deposits can be traced without break by complete transitions into common varieties of igneous rocks containing only small amounts of the metals. It is evident that the processes of natural concentration responsible for these ores took place either before or during the crystallization of the rock from the molten state. This is the process known to the geologist as "magmatic differentiation." The actuality of this process is amply demonstrated not only by the gradations of some ores into common igneous rocks but of various kinds of common igneous rocks



THE DISTRIBUTION OF IGNEOUS ROCKS AND ORE DEPOSITS

A COMPARISON OF THE DISTRIBUTION OF IGNEOUS ROCKS AND OF ORE DEPOSITS IN NORTH AMERICA. THOSE ORE DEPOSITS THAT ARE CLEARLY OF SEDIMENTARY ORIGIN HAVE BEEN OMITTED.

into each other; it is indeed the process by which most igneous rocks have been formed. Among the ore deposits that have been formed by magmatic differentiation are essentially all the chromium ores of the world, the important platinum ores of South Africa, and many of the world's nickel ores.

Another great class of ore deposits, though not themselves igneous rocks, are almost always immediately in contact with igneous rocks and may thus be suspected of being related to them in genesis. Usually the rock in which the ores occur is a limestone, and calcite, the principal mineral of limestone, is a common component of the ores. The contact between the igneous rock and the ore is commonly sharp and the igneous rock usually retains its ordinary composition up to the contact. It is evident from such sharp contacts that the ore is not due to digestion of limestone by molten igneous material, nor would such a process offer any explanation of the high metal content of the contact zone. The mineral composition of that zone affords, however, a clue to what has actually occurred. Although the limestone away from the igneous contact is commonly nearly pure calcium carbonate, the contact zone contains not only calcium carbonate but also calcium silicates in the form of a variety of minerals of which garnet is one of the commonest. It is evident that silica has in some way been carried out of the igneous rock shortly after its intrusion and crystallization and has reacted with the calcium carbonate of the limestone to form calcium silicates. At the same time compounds of the metals, principally with sulfur, were introduced. The agents that accomplished this transfer were obviously solutions tenuous and mobile enough to penetrate the most minute pores of the limestone for long distances and probably hot enough to be gaseous. Ores of the preceding class showed us that magmas in many instances contained the metals in abundance; ores of the class we are now considering show that under some circumstances metals and other substances may be carried out of the crystallizing and cooling magma in solution and deposited in the immediately adjacent country rock, particularly if that rock happens to be an easily altered type such as limestone. This is not one of the most important classes of ore deposits, but it includes many fairly large copper and iron deposits, especially in the western United States.

Limestones are not, however, the commonest types of wall-rocks that border intrusive igneous masses. The wall-rocks may be shales, sandstones, schists, or older igneous rocks, all of them less capable of reacting vigorously with the mineralizing solutions than are limestones. What will be the fate of metal-bearing solutions entering such rocks? In the first place some chemical reaction between the solutions and these wall-rocks would be inevitable although less vigorous than with limestone. In the second place these solutions would circulate most actively along fractures in the wall-rocks and in and near such fractures, while the solutions moved farther from their source and their temperature and pressure declined, their metal content would be deposited. Along such fractures would be formed, therefore, the metalliferous veins flanked to various distances on either side by partly altered wall-rock.

This modern concept of the formation of metalliferous veins finds interesting confirmation in certain mining districts in which there is a concentric or zonal distribution of veins of several varieties around igneous intrusions, those nearest the intrusion showing by the kinds of minerals they contain higher temperature conditions of formation than those farther removed. Contact deposits may and often do occur in the same district as metalliferous veins, as, for example, at Clifton and Morenci in Arizona. An

igneous intrusion may, of course, be bordered in places by limestones but elsewhere by other types of rocks, or limestone next the contact may be succeeded by other rocks farther away and metals not deposited as contact deposits in the limestone may travel on to the outlying rocks there to be deposited as mineral veins.

Inevitably there will be situations in which limestone occurs at a considerable distance from an igneous intrusion yet still within reach of the mineralizing solutions. Under such circumstances the mineralizing solutions deposit ores in the limestone but the reaction differs from that characteristic of "contact deposits." The silica of the metal-bearing solutions instead of combining with the lime of the limestones to form lime silicates is deposited in the limestone as silica in the form of quartz, the calcite of the limestone being at the same time dissolved. This is a lower temperature type of reaction than that characteristic of the contact deposits.

It is of interest to inquire what becomes of the mineralizing solutions after most of the metals which they carried have been deposited. In some instances such solutions, probably consisting principally of water, join the general body of ground water that fills the pores and crevices of the rocks for hundreds or even thousands of feet below the surface. In other instances it probably issues at the surface as hot springs which are rather common in mining regions and which often carry the metals in considerable variety though never in commercial amounts. Hot waters containing dissolved metals in small amounts are also encountered in the underground workings of a few mines developing ore deposits of comparatively recent origin, as at the famous Comstock lode in Nevada. They probably represent the dilute modern counterpart of the solutions that at an earlier period deposited the ores.

It is of interest to consider the number of metals that may be yielded in commercial amounts by a single mining district. Especially in the case of iron ores only a single metal may be recovered, but more commonly a variety of metals is obtained even when the mineralization seems to have come from a single type of igneous source such, for example, as granite. Thus at Butte, Montana, where igneous masses of granitic composition seem to have been the common source of all the ores, copper, lead, zinc, gold, silver, manganese and arsenic are commercially recovered. Often, however, it is found that within such a district the relative proportions of the several metals varies with the distance from the supposed source of the mineralization. Thus at Butte copper ores predominate nearer the source and lead, zinc and manganese somewhat farther removed.

If, as most mining geologists have come to believe, many ores have been deposited by solutions coming from igneous rocks during or shortly after their crystallization, then we should expect to find certain types of ores characteristically associated with certain types of igneous rocks. In many instances this is in fact the case. Thus the ores of platinum and of chromium are invariably associated with the dark-colored igneous rocks, the so-called "basic" rocks. In contrast to this the ores of tin are almost invariably associated with granites. Encouraged by such relationships it has been the ambition of economic geologists to definitely relate all the varied ore types to various types of igneous rocks. Thus far, however, these efforts have met with very partial success for several reasons. In the first place certain metals such as copper and iron may be associated in origin either with highly siliceous, basic or intermediate rocks. Nickel may be associated in origin either with highly siliceous rocks such as granites or with basic rocks such as gabbros. In the second

place a single mining district is often characterized by a great variety of ores as well as igneous rocks, and the task of relating particular ores to particular igneous types is a most uncertain one. In the third place the solutions given off by a single type of igneous magma may deposit progressively different types of ores as they travel farther away from the igneous source.

The problem of the temperatures at which the ores related to vulcanism have been formed has always been of interest to economic geologists. The highest temperatures would of course be expected in those ores that are direct crystallizations from the magmas and several lines of evidence, including direct measurements of the temperatures of lavas at volcanoes, indicate that temperatures of 600 to 1,300 degrees Centigrade may have characterized such deposits at the time of their formation. For the contact deposits developed not in the intrusion but in the immediately adjacent wall-rock indirect evidences indicate temperatures of from 500 to 800 degrees. From such relatively high levels the temperatures decline with increasing distance from the igneous source until for some of the more remote ore deposits the temperatures of formation were probably between 100 and 200 degrees Centigrade. Laboratory determinations of the temperature ranges at which some of the characteristic minerals of ores are stable have been of great aid in inferring the temperatures of formation of ore deposits though subject to some corrections for pressure and other factors.

The chemical and physical constitution of the solutions from which the ores related to vulcanism have been deposited is a matter on which there has been wide diversity of opinion and upon which geologists have only begun to accumulate sound knowledge. The magmas from which those ores that are igneous rocks crystallized were highly concentrated and extremely hot solutions, rather closely analogous to the slags formed artificially in our blast furnaces. Even these solutions carried highly volatile components, as is amply evidenced by the steam and other less abundant gases given off at active volcanoes. A few geologists have concluded that the metalliferous veins were also deposited from solutions of high concentration differing from magmas mainly in their greater metal content and have used the term "ore magmas." Most geologists, however, draw a very definite distinction between magmas and the solutions that have been given off by magmas and are responsible for the deposition of ores in the bordering rocks, although admitting that transition types may exist. They are impressed with the prevailingly sharp contacts between the igneous rocks and their wall-rocks which indicate that the magmas have not penetrated the minute pores of their walls. They are equally impressed on the other hand with the evidence present in nearly all mining districts that the ore-depositing solutions have penetrated the rocks in an astonishingly intimate manner, occupying not only minute pores but penetrating where the highest powers of the microscope reveal no pores. This can only mean that the mineralizing solutions were exceedingly mobile solutions, much more mobile than the magmas even at lower temperatures and pressures. They were also capable of dissolving large amounts of mineral matter from the rocks they so intimately penetrated while at the same time depositing other minerals in the place of those dissolved. None of the components of the ores themselves as we find them to-day can explain such mobility. Fusion of the ores as in an open hearth furnace does not produce a highly tenuous liquid capable of intimately penetrating rock pores for long distances. It seems necessary to conclude that the mineralizing solutions owed their mobility to some component that was not deposited with the ores and has since disap-

peared, leaving no direct trace of its former presence. As the reader has already surmised, this component was probably water, first in the gaseous and later in the liquid state. There is ample evidence that water is a minor but omnipresent component of magmas. In the first place steam is by far the most abundant of the many gases given off by magmas at active volcanoes. Secondly, water is an essential component of some of the common minerals of igneous rocks, such as the micas and hornblende, and it must therefore have been present in the magmas from which these minerals crystallized. In the third place the analysis of gases obtained from crushing fresh igneous rocks *in vacuo* shows that water constitutes 70 to 97 per cent. of the total gases collected. Measured in per cent. of the weight of the entire rock, the amount of water revealed by analyses of the freshest igneous rocks obtainable is small, usually a few tenths of one per cent. In terms of volume, however, the percentage of water reckoned as liquid would be 2½ to 4 times as great and reckoned in the state in which it must have left the magma—namely as gas—its volume would be many times, indeed tens of times, that of the rock from which the gases were derived, the exact amount depending of course upon the temperature and pressure of the gas. There would seem to be little doubt therefore of the competence of cooling and crystallizing masses of magma to give off gases —chiefly gaseous water—in sufficient abundance to transport the metals in large amounts and to form ore deposits. If lingering doubts remained they might be dispelled by the high probability, demonstrated by recent work at the Carnegie Geophysical Laboratory, that magmas in the earlier stages of cooling may increase their original water content by absorption from the wall-rocks only to expel it again as cooling progresses further and crystallization goes on.

As to the precise manner in which the components of the ores were transported by the highly aqueous solutions, very little is as yet known. It is easy to understand how some of the common components of ores, such as calcite, may be dissolved in aqueous solutions carrying carbon dioxide gas and precipitated when this gas escapes. Quartz, another common mineral in ores, though difficultly soluble in water at ordinary temperatures is greatly more soluble at elevated temperatures. Many of the metallic components of ores, such as gold, platinum, the oxides of tin and iron and many others, are practically insoluble in pure water even at elevated temperatures. Some special mechanism is necessary for their abundant solution and transport in mineralizing solutions. The problems involved are too varied and intricate to be discussed in a non-technical article, but two general considerations must be kept in mind in any attempts to solve them. In the first place, some of the components of the ores may be transported in those exceedingly fine mechanical suspensions commonly termed "colloidal solutions" rather than in true solution. Among the ores of the type related to vulcanism there are many whose unusual agate-like textures indicate deposition from colloidal suspension. While colloidal deposition is less common than deposition from true solutions, its possibility should be kept constantly in mind. In the second place, even when considering transport in and deposition from true solutions it should be remembered that some of the familiar elements present in our ores may at high temperatures enter into unfamiliar combinations. It has been suggested that such compounds as SiH_4, SiF_4 and H_2SiF_6, as well as compounds of silicon and sulfur, may be important components at high temperatures of the solutions given off by crystallizing magmas.

CHARLES DARWIN AND CHILD DEVELOPMENT

By ARNOLD GESELL, M.D.

PROFESSOR OF CHILD HYGIENE AND DIRECTOR OF CLINIC OF CHILD DEVELOPMENT, YALE UNIVERSITY

"WITHOUT doubt the first three!" This was the emphatic answer which Charles Darwin gave when as an old man he was asked which years of life he considered the most "subject to incubative impressions." There is much evidence that he was deeply intrigued by the phenomena of human infancy.

Darwin's mind ranged over all natural phenomena—geology, botany, zoology, anthropology. The same passionate inquisitiveness as to the genesis of things which caused him to spend years of exacting study on his "beloved barnacles" led him also to set down abundant notes on the behavior of his babies. He was the father of ten—six sons and four daughters, born within a period of seventeen years. The tenderness and sympathetic insight which he displayed as a parent are well known. Less recognized is the significance of his work in the scientific study of child development.

Human infancy is full of enigma. Grave perplexities arose in the minds of pre-Darwinian theologians who tried to explain the imperfection, or as they called it, "the pettishness" of childhood. The problem of crying troubled the discussions of hereditary guilt. Saint Augustine insisted that the crying of a baby is *not* sinful, and therefore does not deserve eternal damnation. We shall see, presently, how Darwin approached this ancient riddle of the infant's cry.

Darwin's perplexities were those of a naturalist. His mind had a scientist's "naked need for ideological order." This order he tirelessly sought.

My first notebook (on the transmutation of species) was opened in July 1837. I worked on true Baconian principles and without any theory collected facts on a wholesale scale. . . . In October 1838, that is fifteen months after I had begun my systematic enquiry, I happened to read for amusement Malthus on Population. . . . My first child was born on December 27, 1839, and I at once commenced to make notes on the first dawn of the various experiences which he exhibited, for I felt convinced, even at this early period, that the most complex and fine shades of expression must all have had a gradual and natural origin.

From the foregoing dates it is clear that the study of infant behavior very early contributed to the formation of Darwin's ideas. He converted the enigma of infancy into one more touchstone for understanding the origin of species. Much as he admired Sir Charles Bell's writings, he could not believe, with Bell, that man had been created with certain muscles specially adapted for the expression of feelings.

And so Darwin began a series of observations and even a few benign experiments on his newborn son, "Doddy."

On the seventh day I touched the naked sole of his foot with a bit of paper, and he jerked it away, curling at the same time his toes, like a much older child when tickled. The perfection of these reflex movements shows that the extreme imperfection of the voluntary ones is not due to the state of the muscles or of the coordinating centers, but to that of the seat of the will. . . .

When this child was about four months old, I made in his presence many odd noises and strange grimaces, and tried to look savage; but the noises, if not too loud, as well as the grimaces, were all taken as good jokes; and I attributed this at the time to their being preceded or accompanied by smiles. When five months old, he seemed to understand a compassionate expression and tone of voice.

The recorded observations of Darwin's infant covered a wide range of subjects such as vision, winking, hearing, anger, fear, pleasurable sensations, affection, association of ideas, reason, left-handedness, moral sense, unconsciousness, shyness,

language, sympathy. Thirty-seven years later (1877) the diary records reappeared as "A Biographic Sketch of an Infant," published in *Mind*, the British Quarterly Review of Psychology and Philosophy. The manuscript was submitted to the editor with characteristic self-deprecation: "I cannot judge whether it is worth publishing, from having been so much interested in watching the dawn of the several faculties in my own infant."[1] Darwin was remembering the "fine degree of paternal fervour" which had prompted him as a young father and scientist to declare, "I had not the smallest conception there was so much in a five-month baby."

Darwin's observations of infants were by no means limited to his first-born. He renewed his observations on Doddy's brothers and sisters, concentrating on the characteristics of instinctive and emotional behavior. The most valuable and systematic data were incorporated in his famous essay on "The Expression of the Emotions in Man and Animals" (1872). Darwin had first intended to treat the subject in a single chapter of his "Descent of Man," but the essay inevitably expanded into a book—a book which a theological reviewer immediately described as "the most powerful and insidious of all the author's works."

This volume exhibited in an eminent degree, as his friend A. R. Wallace remarked, the author's restless curiosity and an insatiable longing to discover underlying causes. Darwin left no stone unturned in his search for data. He carried on a heavy correspondence, circulating printed inquiries among physiologists, physicians and missionaries, on items such as follow: (11) Is extreme fear expressed in the same general manner as with Europeans? (4) Do the children when sulky, pout or greatly protrude the lips? (16) Is the head nodded vertically in affirmation, and shaken laterally in negation?

Nothing better illustrates Darwin's method of investigation and his outlook on the phenomena of child development than his studies of the age-old problem of infant crying. He observed frowning, pouting, screaming, tears, weeping in his own children. He plied his friends to make similar observations. In a letter to Huxley he asks Mrs. Huxley "to look out when one of her children is struggling and just going to burst out crying." And he adds, "A dear young lady near here plagued a very young child for my sake, till he cried, and I saw the eyebrows for a second or two beautifully oblique, just before the torrent of tears began. . . ."

Far from being a trivial incidental, the obliquing of the eyebrows and the contraction of the muscles around the eyes became a topic of persistent research. He analyzed Duchenne's photographic records of the facial muscles under galvanic stimulation. He consulted paintings and sculptures. He gathered data from asylums for the insane. He enlisted keepers of the zoo and he also closely watched his own cats and dogs. From London and Hamburg he secured photographs of crying children, many made expressly for him. (He remarks, "I found photographs made by the instantaneous process the best means of observation, as allowing more deliberation." How he would have delighted in the delineations of cinema records had they been available to him!)

Probing deeper into the physiology of the weeping eye he enlisted the help of Professor Donders, of Utrecht, who carried through an elaborate experimental

[1] Darwin added that he would never have thought of sending the manuscript had not an article by M. Taine appeared in translation in an earlier issue of *Mind*. When Taine contributed the original article, "The Acquisition of Language by Children," to the *Revue Philosophique* (January, 1876) he commented that his observations had been interrupted by the calamities of the year 1870—calamities that are now repeating themselves, less than 70 years later.

study on the action of the eyelids in the determination of blood flow from expiratory effort. Even after the publication of the volume on "Expression of the Emotions," Darwin kept in touch with Donders, pursuing still further the problem of orbicular contraction. "I think," he writes, "it would be worth while to ascertain whether those born blind, when young, and whilst screaming violently contract the muscles round the eyes like ordinary infants. And, secondly, whether in after years they rarely or never frown." Always alert to alternative possibilities, he continued with characteristic avidity for facts, "If it should prove true that infants born blind do not contract their orbicular muscles whilst screaming (though I can hardly believe it) it would be interesting to know whether they shed tears as copiously as other children."

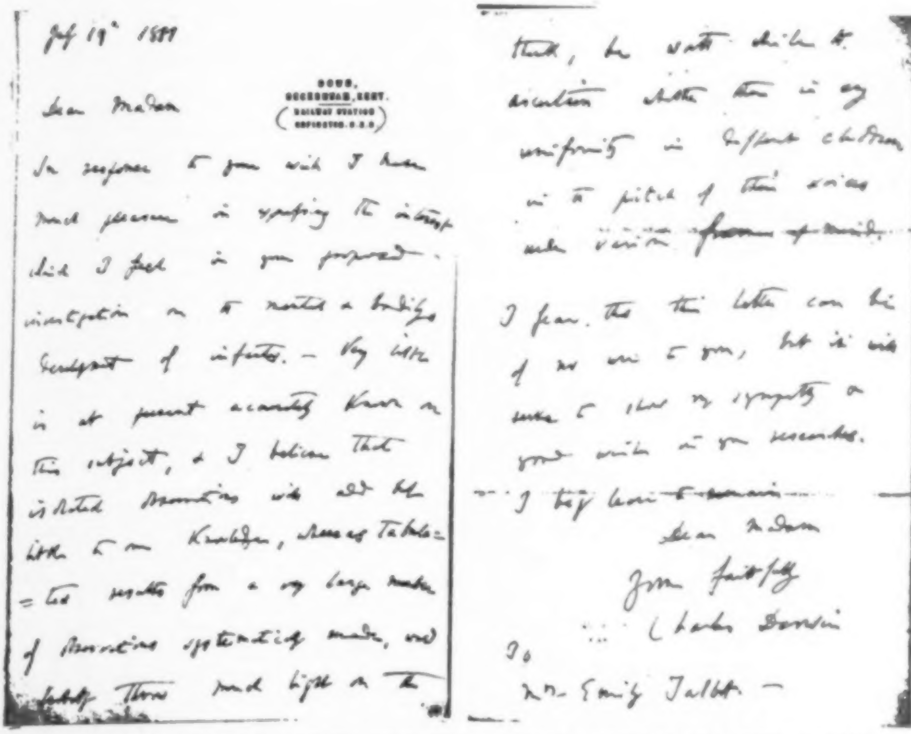
It was not Darwin's habit to terminate his investigations. Soon after publication he began to revise his volume on "Expression." His cousin, Galton, called attention to an omission. "Was it not universal among blubbering children (when not trying to see if harm or help was coming out of the corner of one eye) of pressing the knuckles against the eyeballs, thereby reinforcing the orbicularis?" Almost apologetically, Darwin says he should have thought of this point. "As far as my memory serves, they do not do so whilst roaring, in which case compression would be of use. I think it is at the close of the crying fit, as if they wished to stop their eyes crying, or possibly to relieve the irritation from salt tears. I wish I knew more about knuckles and crying."

Darwin's approach to the problem of child behavior is comparative. He is equally interested in the pouting of the European child, of Kafir, Fingo, Malay, Abyssinian, orang and chimpanzee. He finds that discontented primates protrude their lips to an extraordinary degree, Europeans to a lesser degree, but that among young children lip protrusion is characteristic of sulkiness throughout the greater part of the world. He felt certain that our progenitors protruded their lips when sulky and disappointed. Indeed, the study of emotional expression strengthened the conclusion that man is derived from some lower animal form.

Comparative psychology to-day has taken on a limited connotation which makes it almost synonymous with animal psychology. For Darwin, the naturalist, comparative psychology was more capacious; it was truly comparative. He was primarily interested in phyletic implications, and the breadth of Romanes' work in this field appealed to him. In a letter (to Romanes, 1878) he compared half playfully, half seriously, the intellect of a young monkey and that of his two-year-old grandchild (Frank's son). He saw in the thinking of deaf-mutes "one of the richest of all mines, worth working carefully for years, and very deeply." Again, half seriously, half humorously, he relayed a significant suggestion to Romanes: "Frank says you ought to keep an idiot, a deaf-mute, a monkey, and a baby in your house!"

Darwin was not a psychologist, but he had already inaugurated concepts of life and growth which were to revolutionize the psychological formulations of child development. He profoundly influenced G. Stanley Hall, a young scientist who became a powerful exponent of Darwinism in America. With fertile suggestiveness and comprehensiveness, Hall applied the concepts of evolution to the mind of the child and of the race. Hall also became the father of a nation-wide child study movement which liberalized elementary education and led to scientific advances in the study of child development.

This movement in its mixture of empirical fact-finding and zeal for social welfare was characteristically American.


July 19th 1881

DOWN,
BECKENHAM, KENT.
RAILWAY STATION
ORPINGTON, S.E.R.

Dear Madam

In response to your wish I have much pleasure in expressing the interest which I feel in your proposed investigation on the mental & bodily development of infants. — Very little is at present accurately known on this subject, & I believe that isolated observations will add but little to our knowledge, whereas tabulated results from a very large number of observations systematically made, would probably throw much light on the

think, be worth while to ascertain whether there is any uniformity in different children in the period of their various mental ~~faculties of mind~~.

I fear that this letter can be of no use to you, but it will serve to show my sympathy & good wishes in your researches.

I beg leave ~~to remain~~

Dear Madam

Yours faithfully

Charles Darwin

To

Mrs Emily Talbot —

PAGE ONE AND PAGE EIGHT OF A LETTER WRITTEN BY CHARLES DARWIN TO MRS. EMILY TALBOT, SECRETARY OF THE EDUCATION DEPARTMENT OF THE AMERICAN SOCIAL SCIENCE ASSOCIATION.

It began to take definite shape in the early eighties. Vast areas of prejudice and ignorance had to be overcome; but this did not dampen the ardor of the pioneers who, as we shall see, called upon Darwin for help, the year before he died at Down.

The American Social Science Association had just been founded. In 1881, Mrs. Emily Talbot, enterprising secretary of its education department, issued a circular in which she referred to the new investigative spirit of the time,

> . . . the intelligence of animals, even coming in for a due share of attention. . . . Recently, some educators in this country have been thinking that to study the natural development of a single child is worth more than a Noah's Ark full of animals. . . . In this belief the Education Department of the American Social Science Association has issued the accompanying Register, and asks the parents of very young children to interest themselves in the subject—
>
> 1. By recognizing the importance of the study of the youngest infants. 2. By observing the simplest manifestations of their life and movements. 3. By answering fully and carefully the questions asked in the Register. 4. By a careful record of the signs of development during the coming year, each observation to be verified if possible by other members of the family. 5. By interesting their friends in the subject and forwarding the results to the Secretary. 6. Above all, by perseverance and exactness in recording these observations.
>
> From the records of many thousand observers in the next few years it is believed that important facts will be gathered of great value to the educator and to the psychologist. . . .

This ambitious program did not, however, fail to awaken some resistance and satire. Noah's Ark was still far from a metaphor to large sections of the population who fumed or laughed at Charles Darwin, author, in 1859, of that shocking, green-covered volume entitled, "The Origin of Species." As late as 1889, a lecture on "The Scientific Study of Infant Intelligence" proved a popular suc-

cess by reason of the fun it poked at the new child study. (The lecture was given in "The Mechanics Course" of the Sheffield Scientific School of Yale University, and some months later before the Scientific Society of Bridgeport, Connecticut, by Henry T. Blake.)

With devastating good nature, the lecturer cited the assiduous experiments of Professor Preyer, Monsieur Perez, Herr Kussmaul and Dr. Darwin, with repeated ironic reference to the doctor's family pride in his simian tree-dwelling forefathers. Referring to the registers of the American Social Science Association, the lecturer concluded:

> The registers will go like *la grippe* into every house. Mothers, sisters, aunts, grandfathers, of course, possibly even fathers, will engage in the scientific study of infant intelligence, and the merits of the newly born generation will be rolled into the fold of a permanent record with as much precision and certainty as we used to operate last year's puzzle of "The-little-pigs-in-clover." Every properly constituted University and every Scientific Association will have its cradle of science and its baby chair of philosophy. Under the stimulus of registration also, a vast improvement may be hoped for in the quality of the registered article.

This ridicule was entertaining, and not always amiss. But to-day the ironic prophecy has a new irony—it has come true: Every well-constituted university in America now has a chair or courses in child psychology, and a nursery school for preschool children has almost become a standard feature of the academic campus.

Charles Darwin took the American Social Science Association Register of Infant Development more seriously than our popular lecturer. With a courtesy which was typical of him, he addressed a lengthy letter to Secretary Emily Talbot. This letter is so revealing that it is here reproduced in full.[2]

[2] The original eight-page letter in Darwin's own hand is now in the possession of Professor Marion Talbot, daughter of Mrs. Emily Talbot, who kindly provided us with a photostatic reproduction.

July 19" 1881

Down
Beckenham, Kent
Railway Station
Orpington, S.E.R.

Dear Madam

In response to your wish I have much pleasure in expressing the interest which I feel in your proposed investigation on the mental & bodily development of infants.—Very little is at present accurately known on this subject, & I believe that isolated observations will add but little to our knowledge, whereas tabulated results from a very large number of observations systematically made, would perhaps throw much light on the sequence & period of development of the several faculties. This knowledge would probably give a foundation for some improvement in our education of young children, & would show us whether the same system ought to be followed in all cases.

I will venture to specify a few points of enquiry which, as it seems to me, possess some scientific interest. For instance does the education of the parents influence the mental powers of their children at any age, either at a very early or somewhat more advanced stage? This could perhaps be learnt by school-masters or mistresses, if a large number of children were first classed according to age & their mental attainments, & afterwards in accordance with the education of their parents, as far as this could be discovered. As observation is one of the earliest faculties developed in young children, & as their power would probably be exercised in an equal degree by the children of educated & uneducated persons, it seems improbable that any transmitted effect from education would be displayed only at a somewhat advanced age. It would be desirable to test statistically in a similar manner the truth of the often repeated statement that colored children at first learn as quickly as white children, but that they afterwards fall off in progress. If it could be proved that education acts not only on the individual, but by transmission on the race, this would be a great encouragement to all working on this all-important subject.

It is well known that children sometimes exhibit at a very early age strong special tastes, for which no cause can be assigned, although occasionally they may be accounted for by reversion to the taste or occupation of some progenitor; & it would be interesting to learn how far such early tastes are persistent & influence the future career of the individual. In some instances such tastes die away without apparently leaving any after effect; but it would be advisable to know how far this is commonly the case; as we should then know whether it were impor-

tant to direct, as far as this is possible, the early tastes of our children. It may be more beneficial that a child should follow energetically some pursuit, of however trying a nature, and thus acquire perseverance, than that he should be turned from it, because of no future advantage to him.

I will mention one other such point of enquiry in relation to very young children, which may possibly prove important with respect to the origin of language; but it could be investigated only by persons possessing an accurate musical ear. Children even before they can articulate express some of their feelings & desires by noises uttered in different notes. For instance they make an interrogative noise, & others of assent and dissent in different tones, & it would, I think, be worth while to ascertain whether there is any uniformity in different children in the pitch of their voices under various frames of mind.

I fear that this letter can be of no use to you, but it will serve to show my sympathy & good wishes in your researches.

I beg leave to remain

Dear Madam
Yours faithfully
CHARLES DARWIN

TO MRS. EMILY TALBOT.—

The most concrete contribution which Darwin made to the embryonic science of child psychology was embodied in his volume on "Expression of Emotions." Here he deployed his genius as a naturalist with the same penetration which he brought to bear on barnacles, coral atolls, orchids and earthworms. He did not set himself up as a psychologist; indeed he never entirely escaped a certain naive dualism in his views of the human mind. But it was as a naturalist that he addressed himself to the far-reaching problems of fear, rage and affection. He attacked them with a boldness, objectivity and freshness which make much present-day discussion of similar subjects seem somewhat anemic in comparison. We may well go back to Darwin for vitalization of outlook and even of method. For the scientific study of child development is in need of the naturalist's breadth of vision.

The present year marks a significant anniversary. It was exactly one hundred years ago that Darwin first clearly conceived his epoch-making theory. His chief contribution to the intellectual thought of his time lay in his perception of the gradual genesis of all living things, including the genesis of the human mind. The developmental outlook upon nature and upon its vast web of organic life led to profound revisions in the interpretation of childhood. The concept of evolution with all its corollaries introduced a new and humanizing kind of relativity. Even New England divines, still wrestling with Calvinistic and Augustinian ideas of original sin, softened their doctrines of infant baptism. The new naturalism proved to be a solvent of the gloomier beliefs of fixity and fate. So pervading was Darwin's influence that it has been said that he won for man absolute freedom in the study of the laws of nature.

Without that freedom it would be impossible to penetrate into the meaning of human infancy and into the nature of child development. The modern scientific study of child development is in itself a social assertion of a free spirit of truth. If that spirit is trammeled in any way, man will never know himself, because to know himself he must understand clearly the processes by which he came to be, the processes of child development. So we can scarcely err in paying tribute to Charles Darwin, remover of trammels; even though we realize that science in its most organic sense is a social phenomenon, a cultural product. Darwin, more than any other single individual, initiated the genetic rationalism which now characterizes the investigation of human infancy.

LIFE AND HABITS OF BUMBLEBEES

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THERE are thousands of kinds of wild bees in North America, few of them known to any but specialists, and many of them still unknown to the specialists, still awaiting discovery and description. Among all these, the bumblebees are few in species, usually perhaps about a dozen kinds in any one limited region; but they are so large, so common and so frequently beautifully colored, that one must be stupid indeed not to have noticed them. The ancient Greeks had a word βομβος, or βομβυλιος, which was apparently used for the bumblebee, though very likely for other bees as well. The first of these words becomes in Latin *Bombus*, which is the scientific name of the bumblebees to-day. The second, latinized to *Bombylius*, has been applied to those fuzzy hovering flies, which in the grub state are often parasitic in nests of wild bees. The two modern, semi-popular books on bumblebees are those of F. W. L. Sladen and Otto Emil Plath. The reader will at once notice that Sladen's book, published in England (1912), is called "The Humble-Bee." That of Plath, published in the United States (1934), is "Bumblebees and Their Ways." Humble or bumble, which is it to be? If we go back to the Greeks, or to the scientific designation, it is evidently Bumble. But the Germans write Hummel, and the Oxford Dictionary quotes a passage dating from 1450, referring to "the grashop and the humbylbee in the medow." Shakespeare also wrote it humble bee (Midsummer Night's Dream). The two names were evidently contemporaneous, for we find bombyll bee in 1530, and bumble bee in 1681.

There are many reasons why bumblebees should attract attention. They are not only objects of beauty, but they illustrate certain principles of biology in a striking manner. We often think of life as a struggle for existence between individuals and species, but the principle of cooperation is continually developing among quite diverse groups. It may be said to have begun when the most primitive one-celled creatures united to form many-celled animals and plants, with specialized cells and organs—a form of cooperation which made possible all the higher developments of life. It took on another aspect when social organisms developed in the sea, of such a character that it is hard to say whether we have one animal or a colony of many. Among the insects, we have the wonderful social communities of the bees, the ants and the termites, so closely resembling, in certain respects, human society. Long before our species existed, these insects must have had their organized societies, which were then the highest expression of community life. It is natural to ask, if the insects thus had a start on us by so many million years, how is it that they have not progressed to the human level? The answer must be, that they are governed by instinct, and for that reason, socialists though they may be, are exceedingly conservative. They continue in the same way, age after age, with little change. Man, having in a far greater degree the direction of his own affairs by voluntary efforts, is able to progress, but, alas! by the same token able to make mistakes.

What intelligent person can avoid some curiosity to know how all these things came about? We can not live through the ages, and personally witness the drama of evolution, but we can compare different stages of the process which are still available to us. If we are dealing with objects of art, we can arrange those of different periods, so that it is possible to see the developments from

century to century. In the case of insects, we have indeed some assistance from the fossils, but still more from the numerous species still living, which have become fixed, as it were, at different levels of development. Among the bees, we can arrange series showing the development of the tongue, the wings and other organs. Now the bumblebee, with its long tongue, is an advanced form, yet in its social organization it is much more simple than the honey-bee; it supplies us with a picture of a relatively primitive bee-society, throwing light on the origin of such societies. It is not, however, in the line of ancestry of the honey-bee, though distantly related. The two groups have many differences in structure, and must be regarded as different branches of the same trunk.

Another biological tendency illustrated by the bumblebee group is that of parasitism. There is in nature (even in human nature) a tendency to live at the expense of others. Sladen describes a case in which a nest of *Bombus lucorum* was invaded by a queen of *B. terrestris,* which killed the *B. lucorum* queen and was getting the *B. lucorum* workers to rear her young. This seems to illustrate the beginning of a process which, during the long ages, has led to the evolution of a distinct genus, called *Psithyrus,* the members of which similarly establish themselves in *Bombus* nests, and are in fact quite unable to live independently. There are very many groups of parasitic insects, which must have arisen independently. There are several kinds of parasitic bees, in no way resembling *Psithyrus.* But *Psithyrus* looks so exactly like an ordinary bumblebee that at first sight there seems to be no difference. It is impossible to doubt that these parasitic bumblebees arose from working ancestors, and have now lost the power to provision their own nests. This is shown by the fact that the queens and workers of *Bombus* have a large shining space on the hind legs for the collection of pollen, whereas the *Psithyrus* has nothing of the kind, only a convex surface covered with hair. Sladen found six kinds of *Psithyrus* in Britain, each breeding in the nest of a special kind of bumblebee. Plath observed that in two cases, at least, an American species of *Psithyrus* had two different bumblebee hosts. In any case, however, the parasitism is not indiscriminate, and we find that there is commonly, but not always, a striking resemblance in color-pattern between the parasite and host. One wonders whether the different kinds of *Psithyrus* all came from the same ancestor, or developed independently from different groups of *Bombus;* and why there are not enough sorts of *Psithyrus* to go around, some species of *Bombus* being apparently without such parasites.

With regard to the color pattern, the true *Bombus* not only shows a good deal of variation, but also, in a very curious way, similar patterns in the same district, in bees which are structurally very distinct. Thus in central Asia there is a district where the bumblebees are prettily marked with white, and without careful study, quite different kinds could be confused together.

The bumblebees are especially found in the temperate regions of the northern hemisphere, but also on the mountains, and in South America, where the great Andean range runs north and south, they not only occur at very high altitudes in Peru, but extend to the extreme south, where we find a large species covered with orange hair. Far to the north, they are almost the only bees. Thus on the Pribilof Islands in Bering Sea there is apparently only one sort of bee, the *Bombus kincaidii,* though there are many kinds of flowers.

In New Zealand, there are no native bumblebees, and the red clover did not set seed; but bumblebees were introduced from Europe, and as soon as they became numerous, plenty of good seed was obtained. The native bees of New Zealand,

which are not numerous, are primitive forms with short tongues.

Much has been written concerning the value of bumblebees as pollinators of flowers, especially those with long tubes, such as the red clover and the larkspur.

In some cases, the bumblebee will make a hole in the side of the corolla, and so secure nectar, and perhaps pollen, without paying for it. I have seen a bumblebee slitting the spur of a blue-columbine, a flower normally visited by butterflies. If all the bees took to these burglarious ways, the flowers would in many cases fail to set seed, and the result would be disastrous to all concerned.

What we call "the balance of nature" keeps things going at a fairly even level for very long periods of time. Even the parasites may be valuable to their hosts (as species, not as individuals), by preventing overpopulation. But it must not be forgotten that hundreds of thousands of species have failed and perished, leaving no trace or at best a fossil to show what they once were.

Both Plath and Sladen describe contrivances for rearing and keeping bumblebees in captivity. Such methods make it possible to study the behavior of the insects in detail, and have brought out the fact that the species differ in their methods and their conduct, just as they do in structure, size and color. Accordingly, there are two sorts of classifications, one based on structural characters, such as are used by all students of animals, and another depending on behavior, especially that shown in provisioning the nest. Plath, dealing with the New England bumblebees, has recognized four groups based on habits and has provided rather alarming Greek names to designate them. European authors, in particular, have divided *Bombus* into very numerous subgenera (many of these sometimes treated as genera), but this elaborate classification seems to be of doubtful utility, at least in some respects.

In America, the first great monograph of our bumblebees was that of H. J. Franklin, "The Bombidae of the New World," Transactions of the American Entomological Society, 1912–1913. This is so large and seems so complete that one would suppose the treatment to be final, but another revision will in due course be published by T. H. Frison, of the University of Illinois, who has already issued several important preliminary papers. As Plath points out, the numerous species in the far western states deserve intensive study, and in fact we, of our generation, have many things to discover.

Although we have emphasized the dominance of instinct in the affairs of these insects, it must be admitted that ordinary memory and what we must call intelligence have a part. In the spring, the queen hunts for a nesting site, and chooses a suitable one, often after a very long search. This may be regarded as an instinctive reaction, but what are we to say of her behavior when, having found the right place, she goes about to fix the location in her memory? She flies around in widening circles, until she feels competent to find the place again after a visit to the flowers. Mr. and Mrs. Peckham, of Milwaukee, noticed the same sort of thing in the case of certain wasps, and discovered that the individual wasps were not equally clever. In a moving picture made under Frison's direction, the track of the bee is graphically shown by a moving line, so that we can follow the bee as if we were looking at it from above.

Another example of apparent intelligence, no doubt combined with instinct, is that of the so-called trumpeters. As long ago as 1700, it was noticed that some of the bumblebees, at the entrance of the nest, rapidly vibrated their wings, making a quite audible sound. Some thought this was done for exercise, preparatory to flight, as may be seen among birds; some supposed it was to arouse the colony to work. However, as in the case of the honey-bee, it is for the purpose of venti-

lating the hive, as Plath was able to demonstrate. Colonies kept on the south side of a building showed trumpeting or drumming activities on warm days, soon after the rays of the sun reached the nests. As soon as the sun receded from the nest-box (these were artificial nests) the operations ceased, and not a single bee engaged in trumpeting in the colonies on the north side of the house, away from the sun's rays.

In temperate regions, at least, the bumblebee colonies do not last throughout the year, and in the far north their duration must be very brief. The females which have developed during the summer spend the winter in hidden places, frequently in the sod near the old nests. They come out in the spring and find new nests for the summer. Thus, early in the season, one will find the large so-called queens flying about, but no males or workers. The nests, on being opened, are found to contain a number of tub-like structures, with food for the young, and larvae or grubs in various stages of development. The queen provides pollen for her offspring, but also feeds them by regurgitation. The larvae develop very fast, and Plath states that in about seven days after hatching they are ready to spin cocoons and transform into pupae, which of course do not need to be fed. If all is well, the workers begin to emerge about 22 days after the eggs are laid. These are small, but the queen goes on laying, and the increasingly prosperous colony produces larger and larger workers. Eventually, queens and males are produced, sometimes in large numbers. At length, says Plath, "The old queen, if still present in the nest, has lost her former vigor and gradually becomes more feeble, until at last we find her dead or missing. One by one the workers die off, and in a short time the nest is completely deserted. The comb does not long remain intact, for the work of the scavengers has already begun, and the larvae of the wax moth, *Vitula,* and of the beetle *Antherophagus* soon consume the last contents of the nest which once contained a rich and populous colony." The young queens have left the nest and gone into hibernation.

Otto Plath, now a professor at Boston University, lived when young in Central Europe, and was first interested in bumblebees by the discovery that they made delicious honey. This led to crude efforts to domesticate the bees, and while so occupied he became interested in their habits, and decided that he would write a treatise on their life-history. This boyhood ambition lay dormant for many years, but was eventually the germ from which developed the important and original work published a few years ago.

PHYSICIAN VS. APOTHECARY, 1669-1671

AN EPISODE IN AN AGE-LONG CONTROVERSY

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THE notion—if we may draw conclusions from popular and semi-popular volumes on medical history—that "physician" and "quack" were interchangeable terms in the pre-allergy era dies hard. So insidious is this condescending outlook upon the past that even informed persons overlook the gradations in the "darkness" of earlier medicine. Yet marked distinctions have always existed between healers, and warfare between the trained physician and the "empirick" has been a persistent feature of medical history. In the numerous "health" books of sixteenth and seventeenth century England, the issue constantly appeared; moreover, at times it passed from the incidental stage to that of a full-length controversy. This was the case in 1669–1671 when several physicians sought to remove the "frauds and abuses" of the existing dispensary structure. Needless to say, apothecaries resented the attack and insisted upon their own peculiar value to society.

The opening blast of the controversy, fired by Christopher Merrett, "Dr. in Physick," charged apothecaries with falsifying their medicines and augmenting the number as well as the prices of prescriptions.[1] Merrett specifically denounced the administration of medicines contrary to the prescription, the loading of medicines with honey and other cheaper ingredients, and the use of decayed drugs times without number. In chronic diseases, because of such practices, he said that apothecaries often undid the work of physicians by continuing a given prescription to the patient's grave disadvantage in health and purse. Furthermore, apothecaries often created diseases in men's fancies in order to decoy these victims into the use of physic, made thirty pills when a physician prescribed twenty, and carried medicine appointed for one person to another. Even worse than these abuses, however, was the common practice of recommending and bringing to the patients unworthy physicians, who complied with the apothecaries' interests.

To make the situation worse, said Merrett, such fraudulent practices damaged honest apothecaries who could not compete with the prices set by the dishonest "chymists." Thus, most of the preparations found in the shops were "sophisticated," for the censors, discouraged by the multitude of empirics swarming in every corner, had omitted their wonted searches. Moreover, when the patient was cured and the physician had ended his visits, the apothecary was not above insinuating either the danger of relapse or of another distemper, and accordingly repaired to the physician for a prescription to cure the imaginary disease. By reason of these experiences and the cost of apothecaries, many persons, instead of calling a physician, immediately sought out some common quack or

[1] "A Short View of the Frauds, and Abuses Committed by Apothecaries; as well in relation to patients, as physicians: and of the only remedy thereof by physicians making their own medicines" (London, 1669). Merrett (1614–95) received his M.D. in 1643 and became a fellow of the College of Physicians in 1651. Three years later he began to lecture before the college and thereafter was periodically elected a censor. In addition to the tracts summarized here he edited an herbal in 1666–67 and wrote on urines in 1682.

mountebank. As if these abuses were not enough, apothecaries had always sought the ruin of the College of Physicians, by attacking it in Parliament and traducing it elsewhere.

From a purely therapeutic angle Merrett concluded that the great charges imposed by apothecaries and the nauseousness of their medicines explained why such long-standing and habitual diseases as falling-sickness, convulsions, "winds in the bowels" and gout seldom got relief. Yet apothecaries always blamed the physicians, crying out that the latter were great cheats for not informing the world of their secrets. But revelations would not be safe, the apothecaries' incapacity for practice being manifest by their lack of education. To reform the existing state of affairs, Merrett particularly recommended that physicians mix their own medicines and fill their own prescriptions.

Quite naturally, the charges made by Merrett would not lie unanswered, but before turning to the replies, we may consider additional attacks on apothecaries, attacks apparently stimulated by Merrett's onslaught. Merrett himself reentered the lists in 1670, with a somewhat more comprehensive attack than that of the previous year.[2] In this second pamphlet he promised to conduct his readers to a spot where they could observe the usual method of the "vulgar" physician's examination of his patients. This consisted, he said, of three notions: first, that a patient's grievance was either a discernible evident disease or an inward pain; second, that it was one of the two endemic diseases, scurvy or consumption; third, that it was the pox. This theory, Merrett thought, might be acquired with less industry than fourteen years' study at a university. On the other hand, however he might reproach the vulgar physician for executing his employment with so little ingenuity, he saw greater reason for condemning the "water-gazer," who by examining streams of urine pretended to gratify his patients' curiosity concerning the disease about to overtake them, for some of these medicoes thought to discover as much by the urinal as the astrologer by the globe.

Merrett then turned to uncover the errors which operated to benefit the clerk and the grave-maker. Bleeding was greatly abused by the "hackneys" and was even taken notice of by the vulgar physicians, although their experience told them that it was death in measles and smallpox. Those who knew better had a pleasant sensation on observing how the "hackneys" in the country vomited their patients with crocus, scoured them with jalap and drenched them with water-cresses and brook-lime, terming all diseases, except fevers and agues, the scurvy. Finally, Merrett did not overlook the "groaping" doctors, who pretended great difficulty in discerning a disease when they could not grope about the patient's sides and belly. He concluded by recalling that many physicians had lately deplored the dishonesty, stubbornness and incapacity of apothecaries.

Consequent upon the furor excited by Merrett through his first attack on the frauds and abuses of the apothecaries, he made his third excursion into the controversy in 1670, especially emphasizing the patient's complete ignorance of the apothecary's medicines.[3] When an apothecary had practiced of his own

[2] "The Accomplisht Physician, the honest apothecary, and the skillful Chyrurgeon, detecting their necessary connexion, and dependance on each other. Withall discovery of the frauds of the quacking empirick, the prescribing surgeon, and the practicing apothecary" (London, 1670).

[3] "Self-Conviction; or an enumeration of the absurdities, railings against the College, and Physicians in general; (but more especially, the writers against the apothecaries) non-sence, irrational conclusions, falsities in matters of fact and in quotations concessions, etc. of a nameless person. And also, an answer to the rest of Lex Talionis" (London, 1670).

head and the physician was not called in until extremity of danger, what reason was there, he asked, that the physician should take upon himself the discredit of the patient's death, or why should he teach the apothecary to practice further by curing the patient himself? The tract itself largely was given over to a dialogue between A. (anonymous) and M. (Merrett). A. complained that physicians everywhere, out of malice, denounced the apothecaries and neglected their shops. M. rejoined by leaving it to the reader whether the cheats performed by the apothecaries did not sufficiently justify the physicians making their own medicines.

Among others who participated in the attack inaugurated by Merrett, none perhaps exceeded in eminence Edward Maynwaring, also "Dr. in Physick," who declared that in primitive practice everything pertaining to the physicians' art had passed through their own hands: they had examined drugs, had had a true knowledge of pharmacy and had been expert in medicines.[4] "After that manner the Science of Physick improved." Later, physicians divided their business and devolved part of it upon other men, laying aside the most considerable part of their profession, the preparation and management of medicines. Maynwaring, himself, separated the work of physicians into two parts, theoretical and practical, arguing that they "must prepare medicines, be personally present and active therein," for the physician was a natural philosopher who improved his knowledge of nature by "various Mechanick experiments."

Maynwaring did admit, however, that a physician might depend upon the apothecary's skill in medicines as upon the surgeon's skill in anatomy; at the same time he believed it much more important that the physician look into his medicines than into the "chamber-pot or close-stool." A physician of ordinary parts "with extraordinary curious medicines" could perform more and greater cures and make fewer mistakes than the most knowing and learned theorist with ordinary medicines. The physician, who was not well practiced and skilful in medicinal preparations, but collected his medicines out of books, had but an "empyrical" practice, even though he were very learned, well read and "a long practiser in Physick." The knowledge of an herbal or of books pertaining to animals and minerals by no means made a doctor expert in medicines. A physician ought to be sufficiently acquainted with medicines to give a rational account of every ingredient. In conclusion, Maynwaring offered a few concrete suggestions. Of the drugs imported into England, he said, a fourth part was more fit for the dunghill than for the body of man, and he that took such drugs needed no other disease. His own intention and aim was the improvement of pharmacy and the securing it from being profaned and abused. This could be attained by restoring the ancient reverend esteem of the professors of medicine for that branch of their profession and by excluding all mechanic and illegal trespassers.

Again in the same year, 1670, Maynwaring rode his favorite hobby of physicians making their own medicines.[5] In

[4] "The Ancient Practice of Physick, Revived and Confirmed: as the only way for improvement of this science; security of the sick; and repute of the professors" (London, 1670). Maynwaring (1628–99?) took his M.B. from Cambridge, his M.D. from Dublin, and began to practice in 1663. He condemned violent purgatives and indiscriminate bloodletting and believed smoking to be productive of such diseases as scurvy. During the plague of 1665 he had a good record. Rather ironically, in view of his share in this controversy, his contemporaries regarded him as an "empirick." He wrote extensively.

[5] "The Pharmacopoeian Physician's Repository accomodated with elaborate medicinal arcana's appositely serving to the whole practice of physick exhibited as an exemplar, for imitation and incitation, to the industrious professors in this faculty" (London, 1670).

a second tract he listed medicines under the divisions of head and nerves, lungs, stomach, spleen, and liver, heart and vital spirits, reins and bladder, spine and loins, genital and spermatic parts, external parts, anti-venereal, anodyne and anti-scorbutic and radical. He gave no recipes, but instead supplied directions for the use of the medicines, occasions when required, and the like. Some clue to the contents can be gained from his comment on a certain medicine, "Quintessentia Aurea," for spermatic and genital parts. It helped "to concoct the seed that is crude, thin and waterish; whereby it becomes more effectual for generation; and is assistant to such as want children by exilerating the seed, and endowing it with prolifick spirits." Likewise in dealing with anti-venereal medicines for the "Venereal Lues, called the French disease," he described certain pills as proper for persons "afflicted with that malady, which is not always got by impure copulation, but sometimes by intimate approaches and society, with infected persons of that nature," an interesting appreciation of the infective character of syphilis.[6]

Another "Doctor of Physick," Jonathan Goddard, leaped into the discussion at the same time.[7] He too bemoaned the separation of the preparation of medicaments from their application, and the accompanying indifference of physicians to the actual manufacture. Physicians, he said, if they had put their minds to the task, might have done as expert a job as the apothecaries. Ideally, the separation had the advantage of releasing the physician from inferior employment, but this benefit was lost if apothecaries failed to keep within the limits of their trade and meddled with practice. Goddard also regretted the unreasonable and inequitable state of affairs whereby, when a trained physician had through his industry and ingenuity mastered the secrets of anatomy or had discovered a new medicine, upon his communication of it to an apothecary nothing beneficial would result. The apothecary had betrayed his trust. Furthermore, when the apothecary took it upon himself to practice, he gave the medicine to his patients and so gained a hundred times as large a fee as the physician, the latter curing the patient only once for the ordinary fee and simultaneously teaching the apothecary to do it ever after for innumerable rewards. This condition must ultimately impoverish many physicians.

According to Goddard, it were thus far better to teach the patients than the apothecaries, especially since no dishonor attached to any physician who employed

[6] In 1670 also, Maynwaring published "Vita Sana & Longa. The Preservation of Health, and Prolongation of Life. Proposed and proved. In the due observance of remarkable precautions. And daily practicable rules, relating to Body and Mind, compendiously abstracted from the Institutions and Law of Nature." He found that the brevity of man's life was due primarily to variety, excess in meat and drink, immoderate sleeping, living in unwholesome places, worrying, excessive use of purgatives, ill-prepared medicines, and the like. To regain primitive longevity, man should have fresh air, suitable clothing, a good climate and regular eating habits. Maynwaring also supplied special rules for different temperaments, correlating the passions with bodily functions.

[7] "A Discourse setting forth the unhappy condition of the practice of physick in London, and offering some means to put it into a better; for the interest of patients, no less, or rather much more than of physicians" (London, 1670). Goddard (1617?-75) was a fellow of the College of Physicians, lecturer in anatomy before the college, and Gresham professor of physic. During the Civil War he was a physician in Cromwell's army. He frequently used his laboratory to make experiments for the Royal Society, and he compounded secret remedies, notably, "Goddard's Drops," which were chiefly ammonia with a few frills. He was also credited with having made telescopes. His "Discourse concerning Physick" (London, 1668) partially anticipated the tract discussed here, which according to a postscript had actually been written five years before only to be put aside because of the furor caused by the plague and fire.

himself in making choice and important medicines. Moreover, it was not necessary that physicians should put themselves to the drudgery of making common medicines, for the practice of physic could easily be managed with a "tenth part of the things commonly in use, and the remedies reduced accordingly," a change which would improve rather than damage the healing art. Considering how apothecaries censured the practice of physicians and claimed their own prescriptions to be rare secrets, it was high time for physicians to defend themselves. Further advantages of great importance resulted from the physician's administering his own preparations, namely, his possible discovery of more effectual medicaments and his certainty concerning the strength, efficacy and operation of all his medicines. It was well known that, let a physician write the same prescription to several apothecary shops, the medicines would vary greatly in their sensible qualities. In the meantime, the physician had to answer for all, even though the variations cause a patient's death.

The great objection against physicians making their own medicines was that the apothecaries would be ruined. Yet these persons had taken injurious advantage of physicians by invading the peculiar function of healing, after the physicians had surrendered to them the preparation of medicines. Nevertheless, even if physicians made their own medicines, there would still be ample work for apothecaries as they would always be able to practice upon "the meaner sort." With all his criticism, however, Goddard in conclusion denied any intention of branding all apothecaries, of whom many were thoroughly honest and conscientious and therefore had an important function to perform: he sought only to place the healing art on the surest foundation.

Still another participant, in the person of the much more obscure George Acton, "Doctor of Physick," joined the argument in 1670.[8] While his contribution was somewhat oblique, it nevertheless indicated the extent to which this lively debate had spread through the medical profession. The author "proved" the possibility of curing a disease without a remedy contrary to the disease or at least contrary to its cause. He denied that heat and cold were the efficient causes of diseases; they were merely the antecedents. Finally, he believed that all fevers could be cured with one medicine, as could all distempers of a hot liver or of a cold stomach, and so forth.

These various onslaughts, particularly Merrett's first tract, received an almost immediate reply from one who believed that in counter-attack lay the best defense.[9] After noticing Merrett's statement, that it would seem strange to most men that after thirty years' successful practice, he should now end all dealings with the apothecaries, the anonymous author expressed surprise that a reputed discreet person, such as his opponent, should forsake the ancient laudable procedure and quarrel with the whole company of that profession. He denied Merrett's contention that the apothecary, being less concerned than the doctor, looked only to his own profit and disregarded the patient's welfare. In answer to the conclusion that the greater the patient's charge the greater the apothecary's profit, whereas on the contrary it

8 "A Letter in answer to certain queries and objections made by a learned Galenist, against the theorie and practice of chymical physick, wherein the right method of curing diseases is demonstrated: the possibility of an universal medicine evinced; and chymical physick vindicated" (London, 1670). I have not been able to discover anything about this writer.

9 "Lex Talionis; sive Vindiciae Pharmacoporum: or a short reply to Dr. Merrett's book; and others written against the apothecaries wherein may be discovered the frauds and abuses committed by doctors professing and practicing pharmacy" (London, 1670).

was the physician's interest to cure the patient with the greatest ease, the author reminded his readers that the longer the patient was under the physician's care, the more fees went to the latter. Finally, he objected to the account that "other cheats" like "Matthew's Pills" and "Hugh's Powder" had been cried up as universal medicines, "which the contrary to convince . . . were but to lose time."

A second defense of the apothecaries emanated from that rough-and-ready controversialist, Henry Stubbe.[10] Less anxious to sift the truth than to engage in verbal fireworks, Stubbe promised to be just to the honorable society of physicians and to vindicate the company of apothecaries. After summing up Merrett's charges against the latter, he declared that while some apothecaries might be dishonest, as charged, there was no need to accuse the whole profession in this manner and thus make the honest practitioners suffer. Indeed the latter ought to be the more highly cherished. Moreover, he reminded his readers in response to Merrett's complaints about the "dear bills of apothecaries," the patient that went from the apothecary to "this good doctor" for his medicine, thinking to save by it, would leap from the frying-pan into the fire. He, Stubbe, would plead for such apothecaries as used the best ingredients, made their compositions faithfully and dispensed physician's prescriptions conscientiously. As far as the other apothecaries objected to by Merrett were concerned, there was, after all, a sort of people who, so as they might buy cheap, cared not with what they were served or how they were abused and cheated.

When Stubbe faced Merrett's suggestion that the patient would greatly benefit by the physician's making his own medicines because the whole charge of the apothecary's bill would be saved since the physician would take nothing for his own medicines, he had a great deal of fun. He prophesied that the physicians would charge "handsome sawcy fees"; otherwise, how would the scheme hold water? In reply to Merrett's accusation that during the Great Plague the apothecaries took over the whole practice of medicine, he inquired how it came to pass that the "good doctor" himself had no share in curing the plague-stricken. Did it show public spirit on the part of the physicians to surrender their practice to the apothecaries? As a matter of fact, Stubbe concluded, physicians and apothecaries were embarked on one bottom; if one sank, the other could not expect much safety. To Merrett's declaration that the apothecaries would undo all the chemists in London and possibly ruin the Corporation of Distillers of strong waters, he avowed that the "good doctor," because he feared lest his former chaff would not catch old birds, was calling in more help and leaving no stone unturned that might help to ruin the apothecaries.

In this same year, 1671, a brief compendium of the arguments on the case appeared.[11] Although the author, obviously on the side of the angels, had comparatively little to add to what had already been said, he picked out various flaws in Stubbe's tract, stressing especially its "falsities," ill language and

[10] "Medice Cura Teipsum! or the Apothecaries Plea in some short and modest animadversions, upon a late tract entituled A Short View of the Frauds and Abuses of the Apothecaries, and the onely remedy by physicians making their own medicines . . . From a real well-wisher to both societies" (London, 1671). Henry Stubbe, Stubbs or Stubbes (1632–76) was "a professional literary bravo," whose lively literary career gave him more notoriety as a controversialist than reputation as a physician. Although he achieved some distinction in the latter capacity, he lacked the professional equipment and connections of the men whom he attacked. In addition to the College of Physicians and some of its individual members, the Royal Society also fell under his displeasure.

[11] "Reflections on a Libel, intituled, a plea for apothecaries" (London, 1671).

defense of the tricks and financial practices of the apothecaries. Many quotations from tracts already noted filled its pages, and its chief importance lies in its revelation concerning the extent of the controversy, rather than in any original contribution to the discussion.

Contemporaneously, Dr. George Thomson also turned on Henry Stubbe. Nevertheless, at the same time he believed that, while Merrett's book was to be commended for its practical knowledge, Merrett's experimental theories had cost thousands of lives.[12] Thomson scored the members of the College of Physicians heavily. "They are persuaded the old way is best, to sit in their chair disputing, scribbling medicines, while others are making them. . . . Away, say they, with these new fangled devices of questioning by fact such famous men as we are . . . 'tis enough we have tried again and again, it will bring in a fee." Dr. Merrett, "this supposed reformer of the method of physic, thinks it enough to have lashed the apothecaries to have proclaimed their abuses to the world, as if this were enough to expiate his crime . . . he ought . . . to do penance for making a trade of man's life, for perpetuating thus long a fallacious . . . and pernicious mode of practice . . . that 'tis impossible for any man to discharge his duty aright, who makes not his own medicines with his own fingers." The Thomsons deride the boasting of the Merretts in "compounding medicaments better than the whole Company of Apothecaries."

After 1671, the furor subsided, at least so far as tracts were concerned, but in 1675 Dr. Maynwaring again insisted that the preparation and custody of medicines was the proper charge and duty of every physician.[13] Likewise, he described the "new" mode of prescribing and filing recipes with apothecaries as an imprudent invention and pernicious innovation. The truth of this was demonstrated to his satisfaction from the treble damage and disadvantage that arose to physician, patient and medical science. Thus he argued for the return to, and general conformity with, the primitive practice, and answered the objections brought against the old custom. He likewise discoursed on the excellency of medicines and maintained that skill, knowledge and improvement of medicines were attained not by reading but by practicing, "by preparation and mechanick tryals." The College of Physicians, considering the many inconveniences that emerged from the neglect of medicines, had lately voted it honorable for a physician to prepare his own prescriptions. This he applauded as an excellent innovation because medicines were the physician's business. Not to be expert in the manual preparation of medicines was an absurd deficiency in a physician as well as very dangerous and often pernicious to the sick.

The "imprudent act of our predecessors" in removing pharmacy from the physician's care and management did not perpetually commit their successors. If ruin must fall upon one group, better that the apothecaries should suffer than the physicians, since apothecaries had betrayed the trust reposed in them by

[12] "A Check given to the insolent garrulity of Henry Stubbe, etc. Also, some practical observations exhibited for the credit of the true chymical science. Lastly, a brief contest between the Thomsons and the Merretts, who are the best physicians" (London, 1671.) Thomson (fl. 1648–79) graduated M.D. from Leyden in 1648. He diligently studied the London plague of 1665 and wrote "Loimologia" (1665) reflecting on the physicians (such as Merrett) who left the city during the visitation. In 1665 also he published "Galeno-pale, or a chymical trial of the Galenists, that their dross in physick may be discovered," protesting against contempt for experience and sole reliance on theory. He wrote a number of other medical works, controversial in nature, among which was one opposing excessive blood-letting and which brought him into conflict with Henry Stubbe.

[13] "Praxis Medicorum Antiqua & Nova. The Ancient and Modern Practice of Physick examined, stated, and compared" (London, 1675).

the physicians; therefore, Maynwaring judged it most reasonable that physicians desert them. The safe and speedy recovery of the sick lying in the physician's care was of far greater concern than the profit or maintenance of a particular group of men. The physician that was pharmacopoeian to himself did not delight in the superfluous variety and number of slight medicines, but aimed at a few choice and efficacious ones. The new mode of practice was to draw and frame medicines on a piece of paper, modeling them into several forms, varying for every temperament and case. Here the physician ended his work. Such a scheme of medicine was then transmitted to some apothecary. Justification of the old practice where the physician prepared his own medicines clearly condemned this new method. This discourse, which was liberally spattered with quotations from Cox,[14] Goddard and Merrett, concluded by elaborating the hazards of the "genteel new mode" of prescribing.

A belated reverberation of the controversy appeared in 1685 in "A Direct Method of Ordering and Curing People of that loathsome disease, the smallpox. . . . Being the twenty years practical experience and observations of John Lamport, alias Lampard, practicioner in chyrurgery and physick." Quite apart from his special interest in smallpox, the author referred to the abuses and errors of pretended healers and condemned the existence of too many practicing nurses. If anything may be concluded from Lamport's advertisements of his pills and medicines and the appendix prescribing the proper astrological time to take medicines, he himself was both apothecary and astrologer.

As suggested at the outset, the controversy here summarized should not be regarded as an isolated event in the earlier history of medicine. Although rather dramatic and concentrated, this flareup only expressed the latent hostility between two groups of healers. In addition, it revealed an important and somewhat neglected characteristic of seventeenth century physicians in England—the wide-spread tendency toward reform. So often have writers on the history of medicine in particular and of science in general stressed the martyrdom of the reformer, implying that changes have come with theatrical suddenness through the efforts of some outstanding individual, and in spite of the majority of the profession, so often have these "historians" emphasized the achievements of the man "far ahead of his time," that they have distorted the entire evolutionary process. It is here important to record the wide-spread support of reform among men not notable as pioneers, among men who personified the rank and file of their profession. Obscurantism flourished, in all truth; but the sharp and persistent dichotomy which plays off the lofty genius against massed reaction neglects, if it does not completely deny, the whole realm of historical dynamics.

[14] Probably Thomas Cox (1615–85), a fairly prominent physician of the day, a fellow of the College of Physicians, of which he became president in 1682, and a member of the Royal Society.

RUBBER'S POSITION IN MODERN CIVILIZATION

By P. W. LITCHFIELD
PRESIDENT, THE GOODYEAR TIRE & RUBBER COMPANY

RUBBER'S importance to the modern civilization can be gleaned from its widespread application in tires for motor vehicles—a fact emphasized by our own company's production of its 300,000,000th casing this year. Approaching rubber's place in the sun from another angle—the fact that approximately 4,000,000 workers are engaged in raising, cultivating, collecting, shipping and manufacturing the substance, likewise gives emphasis to rubber's importance.

But rubber's contribution to mankind at the one hundredth year of its practicability (dating from Charles Goodyear's discovery of vulcanization, 1839) aggregates far beyond the acceleration of transport and the employment of labor. Through a ceaseless program of scientific research and development, the rubber industry has wrested from the hitherto unknown many secrets which have extended rubber's use into ever-increasing fields with benefit to each new avenue thus entered.

Rubber's importance as an insulator in the electric world; as hose and conveyer belts for the industrial transmission of fluids and solids; as a shock absorber for all manner of mechanical vibrations; as an indispensable adjunct to the practices of medicine, surgery and sanitation—all add stature to the eminent place rubber has attained in civilization's onward march.

The saturation point of rubber's usefulness has by no means been attained, however. Exploration of its possibilities is not static. Developments still fresh from the laboratories, or passing through the final stages of their embryonic perfection in the research workers' test-tubes, give definite promise of a more healthful, enjoyable, convenient life.

Discovery that uncoagulated latex could be whipped into an aereated froth which could be suspended permanently through chemical reaction, has brought about the introduction of mattresses and cushioning material such as Airfoam. Thus man, long accustomed to cushioning his automobile from road shocks with rubber tires, now is beginning to enjoy restful sleep on a mattress of whipped latex which always resumes its original shape; is non-allergic, germ and vermin-repellent. His living room furniture and the seats of his passenger car, truck, theater and auditorium are being similarly equipped, with rubber as the cushioning medium.

This same material, while comparatively a new product, originally intended primarily for cushioning, already has found practical application in such distantly removed uses as blackboard erasers and powder puffs, illustrating a common characteristic of new rubber products—diversified adaptability.

Even more spectacular is the growing utilization of the rubber hydrochloride to which has been applied the copyrighted name, Pliofilm. Through a series of chemical processes, physical characteristics of crepe rubber are altered in such a manner that the desirable properties are retained and many objectionable properties are lost. The resulting substance is produced in sheets or rolls over a wide range of gauges, beginning with a gossamer thickness of only .0012 inch.

Being inherently waterproof, practically impervious to moisture, resistant to tear and transparent (if desired) in almost any color of the solar spectrum, Pliofilm at first was used widely for raincoats, umbrellas, tea aprons, shower curtains and as a protective and decorative material for many household applications.

But here again, a rubber product well suited to one field of application has branched out into other important spheres of usefulness. To-day the packaging of many commodities has been revolutionized by Pliofilm. All manner of foodstuffs, particularly those susceptible to dehydration (such as cheese) and absorption of moisture (such as crackers), now are being packaged in stabilized rubber chloride wrapping.

Laminated as lining for paper sacks, Pliofilm is being used to retain the freshness and aroma of fine coffee; laminated to burlap sacks, it is protecting sugar and other bulky granular products from moisture. Even oil may be packaged in Pliofilm sacks. From the rubber laboratories also has recently come a treatment for women's hosiery that greatly prolongs their usefulness by making them resistant to snagging and running.

Equally important examples could be outlined almost *ad infinitum,* but I believe that these typical applications cited will serve adequately to illustrate my statement that rubber's contribution to mankind goes far beyond the realms of transport and employment.

Not only do we communicate over and travel between great distances through the utility of the Hevea tree's latex—it protects our bodies from the elements; it keeps our food fresh and wholesome; it protects us from disease or gives aid in reclaiming us from injury and affliction; it is the fluxing material without which modern living would be either impossible or tremendously restricted.

BOOKS ON SCIENCE FOR LAYMEN

A NATION OF ELDERS[1]

THE average span of life of mankind is steadilly increasing. To-day there are more elderly people than ever before; to-morrow we may expect that a still greater percentage of the population will have reached or passed "three score and ten." Ninety years ago, in 1850, but 2.6 per cent. of the American people were 65 years or over. By 1940 the percentage will have nearly trebled to 6.3 per cent. In 1850 more than *half* the population was under 20 years of age, whereas now but 35 per cent. or slightly more than *one third* of the United States population is under twenty.

An era of increased longevity is upon us. These shifts may be expected to continue, albeit with reduced tempo, for there is a biologic limit to the normal span of life. The consequences of these changes which are making us a nation of elders reach far and wide and affect every field of human endeavor. Medical, economic, sociologic and political problems are pressing for solution. The mind of the nation is changing: it is growing older. Perhaps this implies it is growing wiser, perhaps not. We hope it is, for the hope to live long and usefully is well-nigh universal.

The problems of old age are not new, but the urgency for their solution has never been as great as it is now. If we as a people are to gain by these consequences of preventive medicine (every life saved from premature death is a potential senescent) we must need to know far more than we do now concerning the problems of ageing. The appearance of this extremely comprehensive volume is most timely.

Ageing is a biologic process common to all living organisms—perhaps a process common to all matter. Although the inception of ageing starts with the conception of a new organism, the changes are long submerged in the conspicuous activities of growth, development and maturation. It is only after maturity has been reached that senescence makes itself felt as an active process. This publication considers the problems of ageing from a broad biologic view-point. The evidences of senescence in all forms of life are discussed. Ageing in plants, protozoa and insects differs from the processes observed in mammals and higher forms of life. The changes inherent with old age in the various tissues and systems of the body are probed and exhaustively analyzed.

Although prepared primarily for physicians and biologists, the book contains much of great interest to the general reader. Dr. Cowdry's careful selection of the twenty-six eminent contributors has resulted in a most scholarly and thorough presentation. Each chapter includes a brief but well-chosen bibliography. Medicine must needs concern itself more and more with the particular problems of health maintenance in the aged and with the degenerative diseases characteristic of later life. Geriatrics has a significant future. It is upon biologic foundations such as those summarized in this book that the application of medical science rests.

Despite the extensive scope and ambitious program of the work in recording the intensive studies of many specialists, the chief value of the book lies in the implication and recognition of the numberless problems remaining unanswered. It attacks the problems from the roots

[1] *Problems of Ageing: Biologic and Medical Aspects.* Edited by Edmund V. Cowdry. Illustrated. xxx + 758 pp. $10.00. Published for the Josiah Macy, Jr., Foundation by Williams and Wilkins Company.

by asking the fundamental questions: What and why are the biologic mechanisms of ageing?

E. J. STIEGLITZ

ANTS VS. MEN[1]

JUST at the moment when our present civilization appears to hang in the balance comes this book. It treats of a subject that has always intrigued curiosity of biologists and laymen alike—the concerted behavior of ants as it illustrates the similarities and differences between their social life and that of the paragon of organization among the primates, *Homo sapiens.*[2]

The ants are geologically far older than man, for we know that they made their appearance on earth well before Tertiary times. They were, in fact, abundant some 60 million years ago and at that time were essentially similar to the present living species in their bodily structure and unquestionably also in their habits. Thus, a type of social organization that has been so successful and weathered the vicissitudes of such an interminable period without any fundamental changes should be worthy of searching comparison with the vagaries of human "progress." The latter, now sky-rocketing about with the vigor of early youth, still has some ten thousand times longer to go before it reaches the ripe age of the ants' social history. Will our own civilization land hopelessly cracked up, or will we finally adopt the mechanized behavior of the ant that has proven so satisfactory for a type of purely instinctive invertebrate animal?

Before dealing with this comparative behavior "Of Ants and Men" Dr. Haskins reviews the origin and evolution of ants as fully as may be in the light of our present knowledge, and gives an account of the present organization of the colony in the several groups of the family Formicidae. He shows how the more individualistic and primitive types have given way before the more specialized ones whose dominance appears to be correlated with the disappearance of individual variations in behavior.

There is, of course, an account of dulosis, or slavery, among ants, of parasitic ants and of the numerous myrmecophiles that have taken up their abode in ant-nests. The consequences of these social phenomena are then considered at some length in connection with the life and prosperity of the colony and their final effect upon the species concerned. Several pages are devoted to a detailed account of two species (*Pheidole megacephala* and *Iridomyrmex humilis*) that have spread widely in warm countries during recent times, driving out the indigenous ant-fauna over the extensive areas that they have exploited. Finally, meeting in Madeira in a fight to the finish where the militant Pheidole had already taken possession, an unexpected outcome has been the usurpation of the island by the gentle Iridomyrmex which now holds sway after having completely ousted the earlier invaders. Such occurrences offer much food for thought in connection with human behavior, and the author points out many additional analogies of sociological interest, particularly with reference to parasitism, slavery and conquest.

As he finds that the organization of the ant colony appears to be most closely analogous to the several forms of totalitarian government in man, such as communism and fascism, the author appears to believe that the latter represents a later evolutionary stage in human relations, especially as this is the pattern among the higher groups of ants. As we find the more "democratic" primitive

[1] *Of Ants and Men.* By Caryl P. Haskins. Illustrated. vii + 244 pp. $2.75. Prentice-Hall, Inc., New York.

[2] Or, as some taxonomists prefer to call him, *Homo americanus* var. *europaeus*, thus sidestepping the connotation of sapience.

ants giving way to the more "totalitarian" higher types, we may, therefore, perhaps anticipate an enduring multimillennium of totalitarianism for the human species. Whereupon I feel tempted to revive the Mosaic legend that God created man in his own image, and, we trust, with a less restricted intellectual horizon than that enjoyed by the ants who have been satisfied with fecundity, conquest and a consequent domination of the insect world.

The book is extremely well written, and although the author is primarily a general physiologist who has undertaken the study of ants as a secondary interest, there are few errors that the reviewer has been able to detect. It is heartily recommended to the wide audience for which it is intended, including all biologists, sociologists and those really interested in general science. In view of the present state of our human world, it has appeared at a particularly opportune time to disseminate much information not extensively known and to draw many illuminating comparisons between ants and men.

CHARLES T. BRUES

HUMAN HEREDITY[1]

THIS book is an outstanding achievement in the popularization of science. Mr. Scheinfeld is a layman, not a scientist. Nevertheless, he has written an account of the difficult science of human heredity that is sound, interesting and highly informative. The lay reader will certainly learn much from "You and Heredity." But thanks to the expert collaboration of Dr. Schweizer, the book should also satisfy the critically minded geneticist, and serve to broaden the teaching biologist's knowledge of many unusual phases of human biology. Furthermore, whoever the reader, he will be entertained by the vivid and piquant tables and diagrams (many in color) and the sprightly style.

Since the author is not a professional scientist it is of interest to inquire as to the motivation that led him to write this book. "When I began my study of the subject, it was solely for the purpose of utilizing some facts of human heredity in a projected work of fiction. Before long I discovered that the findings in the field so completely shattered my own preconceived notions and the ideas held by all but an initiated few as to obliterate my original plans. I became convinced that the most interesting task before me was to acquire as thorough a knowledge of this subject as I could and then, in some way, to communicate it to others." This approach to the study and the popularization of a scientific problem is significant in respect to the relation between science and society. It presents the impact of science on culture in a somewhat novel form, and it introduces a rather new type of factor aiding the diffusion of the fruits of scientific research from the restricted field of the laboratory to wide-spread social acceptance.

The book begins with an introduction to the bare essentials of genetic principles, and then goes on to discuss in detail the inheritance of eye, hair and skin color, of features, body form and structure, and of many pathological conditions ranging from color-blindness to peroneal muscular atrophy. Constant reference to the genetic problems and probable results of various human matings make these sections of the volume particularly appealing to those who take parenthood seriously. Much of the remainder of the book is devoted to an illuminating discussion of questions having social significance, such as the interaction of heredity and environment in the determination of intelligence, crime, personality and certain diseases, and the problems of eugen-

[1] *You and Heredity.* By Amram Scheinfeld, assisted in the genetics sections by Dr. Morton D. Schweizer. Illustrated. xvii + 434 pp. $3.75. Frederick A. Stokes and Company.

ies and of "race." Mr. Scheinfeld's main conclusion from his study of the social aspects of his subject is a very significant one; ". . . at the moment we have no need to stake our hopes for an improved mankind on future genetic findings or on radical changes in our biological make-up. . . . We have in our biologic genes now in circulation, . . . all the potentialities for a race of supermen—*if we can properly direct and control our environment.*" (Author's italics.) This is a conclusion to be especially pondered by eugenists.

"You and Heredity" is not without some faults. Students of evolution, for example, will question the author's claim that Darwin gave complete credence to the theory of the inheritance of acquired characteristics, and many will not agree with all his political views. But these shortcomings are of minor importance. What strikes one most is the many excellences of the book, and it is these that are its recommendation to any one interested in the subject of human heredity.

ALEXANDER SANDOW

A SCHOLARLY BOOK FOR SCHOLARS[1]

THIS, "The North American Assault on the Canadian Forest," is not the first book on the ravaging of a great resource by covetous gentlemen. It is, however, one of the most carefully detailed and worked out of the lot. Perhaps a too great realization of the danger of relating this "special phase of economic history" in accordance with a method that is romantic leads the editor, who is the author of the major section of the book, to be over-cautious in his presentation. There are for the layman perhaps three major purposes in a book of history. The first is to relate facts; the second is to present a fascinating and vigorous story; and the third is to reform. This book clings tenaciously to the first. There are two important human elements that seem to have been lost sight of in the creation of this work. At least two. The first of these is the building of tremendous fortunes and, in some cases, the loss of these. This phase of the whole panorama, the authors have either failed to see or else they have feared to deviate from the straight and narrow processes of history-making to present a possible, colorful picture. The second of these is the life—in some cases the exaltation, in others the degradation —of the laborers who made possible the great exploit.

Regarding the features that pertain to reform, perhaps the work has been done by Thorstein Veblen, at least so far as the forests this side of the Canadian border are concerned. Anyway, the attempt to teach a lesson by picturing the processes by which a great resource is despoiled would be only futile, probably. The layman, however, expects the world to be made over according to some idealistic pattern, and he therefore likes a homily in what he reads. But this book is not written for the average reader; it is written for students of economic and factual history. It should be noted, therefore, that an important purpose of history writing has been fulfilled. The facts are well presented, and the economic phases of the whole development are likewise revealed. It is refreshing to see that at least historians on the Canadian side are interested in so important a matter as the economics of the situation.

To summarize, it may be said that so fine a work will probably fail to meet the needs of the average reader, it is a book designed for scholars rather. It is one of a series to which significant individuals are devoting their time and effort.

J. E. THORNTON

[1] *The North American Assault on the Canadian Forest.* By Lower, Carrothers, Saunders. Illustrated. xxvii + 377 pp. $3.75. Yale University Press.

UNIVERSITY HALL OF THE OHIO STATE UNIVERSITY.

THE OLDEST BUILDING ON THE CAMPUS. JOINT SESSIONS OF AMERICAN SOCIETY OF ZOOLOGISTS AND GENETICS SOCIETY OF AMERICA WILL BE HELD IN ITS AUDITORIUM.

THE PROGRESS OF SCIENCE

SCIENTISTS ASSEMBLE AT COLUMBUS

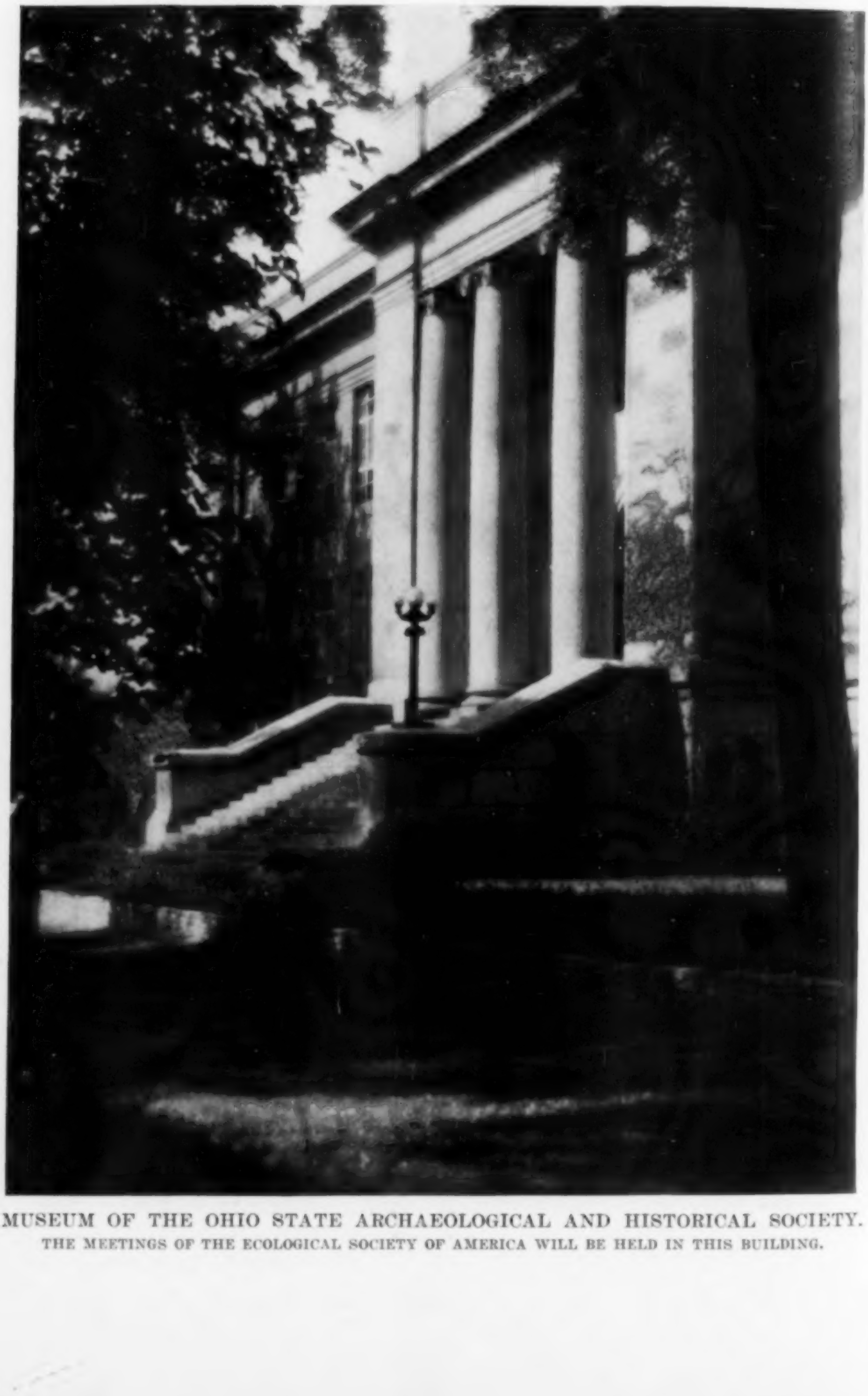
IMMEDIATELY after next Christmas scientists from all parts of the country, five thousand strong, will be on their way toward Columbus, Ohio, to attend the one hundred fifth meeting of the American Association for the Advancement of Science, which will be held from December 27 to January 2.

During the first seventy years of the existence of the association (it was organized in 1848), it could meet in any university town, for its programs consisted of a dozen or two sessions at which a few general addresses were delivered and a few score papers were presented. With the enormous expansion of science during the past thirty years the membership of the association has grown until it now exceeds twenty thousand, and the programs of its meetings have increased proportionally. At the meeting in Columbus about two hundred sessions will be held before which approximately sixteen hundred papers will be presented. The details necessary for arranging these programs are largely in charge of the secretaries of the sixteen sections of the association and of the secretaries of those of the one hundred sixty-six affiliated and associated societies that join in the meeting.

In order to provide facilities for presenting the programs of these sections and cooperating societies, it is necessary to have ready for simultaneous use about sixty meeting rooms, each equipped with a stereopticon projector and having an operator always available for darkening the room and serving the machine, and year by year steadily increasing numbers of motion picture projection machines are required, for the sequences in which phenomena occur are sometimes of the highest importance.

The foregoing statement of the accommodations and facilities that are necessary for meetings of the association explain why they must be held in such large cities as Columbus. In important respects Columbus is an ideal city for a meeting of the association, for it is located near the center of population of the country and includes within three miles of its center the Ohio State University with fifty buildings and more than seventeen thousand students. This great institution provides not only meeting rooms and numerous facilities, but the 1,100 members of its teaching staff, as well as its graduate students, furnish numerous participants in the programs and large audiences. Moreover, the Ohio Wesleyan University is only twenty-two miles away. Virginia has been known as the home of presidents of the United States; Ohio is preeminently the home of colleges. It is said that whenever its early ministers were in doubt they would found colleges. However that may be, nearly every town of any size in Ohio is the seat of a college where science is taught, whatever may have been the primary purpose of its founding. The meeting of the association in Columbus will be an inspiration to all these centers.

How fast the world changes in our day as a consequence of science and its applications! Central Ohio was opened for settlement in 1787, and the first residence, a log cabin, was erected in 1798 in the area now occupied by Columbus. In 1812 the Congress of the United States appropriated certain "refugee lands" in that region for the use of Canadians and Nova Scotians who had sympathized with the Colonists in their struggle for independence in the Revolutionary War. The Borough of Columbus was incorpo-



MUSEUM OF THE OHIO STATE ARCHAEOLOGICAL AND HISTORICAL SOCIETY.
THE MEETINGS OF THE ECOLOGICAL SOCIETY OF AMERICA WILL BE HELD IN THIS BUILDING.

rated in 1816. In 1834 Columbus, with a population of 3,500, was incorporated as a city. At the outbreak of the Civil War its population was only 18,000; in 1900 it was about 125,000; now it is about 500,000, a four-fold increase in forty years.

It is not difficult to explain the development of Columbus and other large cities in Ohio. The state has a fertile soil, great resources in petroleum and natural gas, and enormous quantities of coal. Indeed, in one area there are forty seams of coal that were laid down successively in the days when the waters of shallow seas periodically spread over what is now the central part of the United States. Fortune added to these almost unparalleled natural resources by connecting the enormous iron ore deposits of the Lake Superior region with the coal areas of the Ohio valley by the Great Lakes. Finally, Ohio was settled by hardy and progressive pioneers.

One thing remained for the development of a great industrial state, and that was science. It came and worked a miracle of transformation that no one could have anticipated a century ago. Physical evidences of accomplishments are obvious and often are taken as the measure of the progress of civilization. But really they are the means to finer ends, as the roof and walls of a house are only to shut out the elements and the world from the sacred home that is within. At the meeting in Columbus the boasting will be of the achievements of the mind—of explorations into remote parts of space and into inner recesses of matter, of the long history of the earth and of its future, of the evolution of life and of the curing of disease, of the rise of man and of the progress of civilization. Instead of being austere, except in its insistence on the truth, science is joyous and optimistic. The general programs of the meeting prove the statement. The address of the retiring president of the association, Dr. Wesley C. Mitchell, of Columbia University, is on "The Public Relations of Science." The title of the

HORTICULTURE AND FORESTRY BUILDING
WHICH WILL HOUSE THE HORTICULTURAL SCIENCES.

annual Sigma Xi address, to be delivered by Dr. Kirtley F. Mather, of Harvard University, is "The Future of Man as an Inhabitant of the Earth." And the annual address under the auspices of Phi Beta Kappa is by Dean Marjorie Nicolson, of Smith College, on "Science and Literature."

Science is generous, every discovery being shared gladly with the whole world. No preacher or priest will breathe more truly the Christmas spirit of Peace on Earth and Good Will to Men than will the scientists in their meeting in Columbus, Ohio, from December 27 to January 2. Indeed, many troubled minds are looking anxiously toward science with the hope that it will be able to provide a new and better foundation for ethics and possibly religion. F. R. Moulton

PROFESSOR CORNEILLE HEYMANS, NOBEL LAUREATE IN PHYSIOLOGY AND MEDICINE FOR 1938

According to Oswald Schmideberg, the founder of the science of pharmacology, the main purpose of those working in this field should be the elucidation of physiological phenomena by studying the reactions of living systems to chemical agents. The depth of this conception is shown by the caliber of the contributions which those who have been guided by it have been able to make to the sum of human knowledge, and no more striking commentary could be desired than this, that the Nobel Committee, custodians of the highest award that can come to a medical scientist, having in 1936 honored two pharmacologists, Henry Dale and Otto Loewi, for their work on humoral transmission of the nerve impulse, now award the prize for 1938 to Corneille Heymans, professor of pharmacology in the University of Ghent, for the new light that his studies have cast on the regulation of respiration and the influence of drugs upon it.

The name of Corneille Heymans first became widely known when, in a paper published in 1927, his father and he announced the discovery of respiratory changes produced reflexly by alterations either in the pressure or in the chemical composition of the blood in the arch of the aorta. Almost simultaneously, in publications stimulated by H. E. Hering's discovery of the importance of carotid sinus reflexes to the control of blood-pressure and heart rate, attention was directed by Danielopolu and his collaborators to respiratory reflexes, similar in essential respects to those described by Heymans père et fils, but emanating from the carotid sinus region instead of the aortic arch. Corneille Heymans then set out to investigate the carotid reflex zone, as he told me (and like most who have come to work in this field) in the most skeptical frame of mind possible, but it was not long until he had convinced himself that this source of reflexes is certainly as important as the aortic region, and at the same time is vastly more accessible to experimental approach. He confirmed Hering's results with respect to the "check-rein" effect exerted on heart rate and vasomotor center by the reflexes aroused in the carotid sinuses and aorta by increase in intra-arterial pressure. He showed clearly, for the first time, that the respiratory center responds like the vasomotor in this respect, being reflexly inhibited by rise in intracarotid pressure, reflexly stimulated by a fall. But his entirely new and undoubtedly most important contribution is the discovery—in carotids as well as aorta—of another reflex system responsive to chemical agents and not to pressure, and producing stimulant instead of inhibitory effects upon blood-pressure and respiration. He demonstrated that these chemoreflexes arise, not in the carotid sinuses (as the pressure reflexes do), but

DR. CORNEILLE HEYMANS BY THE MEMORIAL TO HIS FATHER

THE LATE PROFESSOR J. F. HEYMANS, IN WHOSE HONOR THE J. F. HEYMANS INSTITUTE WAS FOUNDED. THE PLAQUE IS IN THE LOBBY OF THE INSTITUTE BUILDING.

THE J. F. HEYMANS INSTITUTE AT GHENT, BELGIUM.

in some proximal part of the external carotid system, and he accepted De Castro's claim, based on morphological grounds, that the chemically sensitive receptors are located in the carotid body, which has subsequently been proved true. He showed that the chemoreceptors can be stimulated by all three of the main chemical influences that physiologists have long associated with the automatic control of respiration, namely oxygen-lack, increased acidity and increased carbon dioxide tension in the arterial blood. Thus he introduced an entirely new element into discussions of the physiology of respiration. He demonstrated that the stimulant effects of oxygen-lack on respiration and circulation are dominantly if not exclusively due to these reflexes, the direct effect on the nerve cells of the centers being a depressant one—a conception that has greatly clarified our understanding of this subject, that already has had an influence upon psychiatry, as evidenced in the explanations now current for the beneficial effects of metrazol and insulin in the treatment of mental diseases, and that will almost inevitably have important bearing upon aviation medicine. He found that a number of drug actions, such as the respiratory and circulatory stimulant effects of cyanides, sulfides and small doses of lobeline and nicotine, are exerted on these chemoreceptors and not, as previously supposed, on the centers themselves. His work has been repeated (again in the most skeptical frame of mind possible) by a number of others, and no one who has remained in the field long enough to acquire the requisite technique has failed to confirm his general conclusions. So thoroughly has Heymans explored this new physiological territory that it is scarcely possible now to make an observation that has not already been made and recorded by him. There is room for difference of opinion about some of the fundamental points involved, largely because there are greater differences among individual animals, among different species and under different experimental conditions, than he has taken cognizance of in drawing conclusions from his experiments. Yet even though final answers to the

questions raised by his pioneer experiments are not yet at hand and will not be until a considerable amount of laborious experimentation has been carried out, this can not detract from the service he has rendered the cause of medical science by discovering a chemoreflex system previously unknown and thus stimulating new types of thought and investigation. I am sure that his thousands of friends and admirers in this country will join in congratulating the Nobel Committee on their happy choice and in extending to the new laureate heartiest felicitations as well as best wishes for the future.

The course of events leading to this pleasant culmination might perhaps be studied with profit by those who are entrusted with the destinies of the various peoples of the world: a Belgian takes up a challenge derived by a Rumanian from the writings of a German and is rewarded by the Swedes, while the entire scientific world shouts its approval. Differences of opinion among the nations can still be settled amicably and yet with dignity and profit to all concerned—in the realm of science.

Carl F. Schmidt

University of Pennsylvania

THE FORTHCOMING EXHIBITION AT THE CARNEGIE INSTITUTION OF WASHINGTON

One of the interesting scientific exhibitions of the year will be the annual exhibition of recent research developments by the Carnegie Institution of Washington. The institution, following its usual custom, will present the results of some of its current researches at its next exhibition, which will be held at its Administration Building, Sixteenth and P Streets, N. W., Washington, D. C. The exhibition will be opened to the public on Saturday evening, December 16, and will remain open on the following Sunday and Monday.

In past years the range of its exhibits have covered a wide field, as is to be expected in view of the scope of the scientific activities of the Carnegie Institution itself. Founded in 1902 by Andrew Carnegie and reincorporated by act of the Congress of the United States in 1904, with Elihu Root as chairman of its board of trustees and Daniel Coit Gilman as its first president, its general purposes are "To encourage in the broadest and most liberal manner investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

In its earliest stages these objectives of the institution were accomplished through grants of funds for specific researches, but later efforts were directed towards certain major projects, the pursuit of which required longer periods, increased staff and greater concentration of funds. This tendency towards concentration on important complex problems, which could only be attacked effectively through the united and correlated efforts of groups of scientifically trained individuals, led to the organization of departments and divisions devoted each to its general subject under the leadership of able and experienced investigators. More especially was this true since the institution attempts to advance fundamental research in fields not normally covered by other agencies.

In line with these policies of the institution, its Division of Animal Biology, under Dr. George L. Streeter, comprises the Nutrition Laboratory in Boston, the Department of Genetics with its Station for Experimental Evolution and Eugenics Record Office at Cold Spring Harbor, Long Island, the Department of Embryology in Baltimore, and the Tortugas

THE ADMINISTRATION BUILDING OF THE CARNEGIE INSTITUTION OF WASHINGTON
WHERE THE EXHIBITS WILL BE HELD IN DECEMBER.

Marine Laboratory in Florida. The Division of Plant Biology, under Dr. H. A. Spoehr, includes the Desert Laboratory at Tucson, Arizona, and Department of Botanical Research, the Coastal Laboratory at Carmel, and the Central Laboratory for Plant Physiology at Stanford. This division also operates dune gardens at Santa Barbara, Calif., and transplant gardens at intervals from the base to the summit of Pike's Peak. Extensive palaeobotanical researches and studies of historical climatology have long been carried on also by this division.

The Geophysical Laboratory, under Dr. L. H. Adams, and the Department of Terrestrial Magnetism, under Dr. J. A. Fleming, are both in Washington, D. C. The institution also operates magnetic and electrical observatories in Peru and Australia. The Mount Wilson Observatory, under Dr. W. S. Adams, is at Pasadena, Calif. The Division of Historical Research, under Dr. A. V. Kidder, which includes the Sections of Aboriginal History, Post Columbian History and the History of Science, is in Cambridge, Mass.

The results of the numerous researches already completed or currently in progress by the large staff of the institution in its several departments and divisions appear in current scientific magazines of various societies, and in hundreds of volumes of monographs and other scientific publications of the institution itself which are sent gratuitously to all the principal libraries of the world, the object of the distribution being to make the research materials readily available to scientists and others interested, wherever they may be.

This same objective of the wider application of knowledge is the guiding purpose of the institution in its annual exhibition of some of the more recent

advances in science, which will be open to public view in Washington in December, together with a series of public lectures generally related to the subjects of the exhibits demonstrated at that time. T. H. D.

AWARD OF THE RUMFORD MEDALS TO PROFESSOR GEORGE RUSSELL HARRISON

In the year 1753 in a farmhouse in North Woburn, Mass., there was born to Benjamin Thompson and his wife, Ruth Simonds Thompson, a son named Benjamin.

During his boyhood the lad showed an intense interest in scientific matters, attended scientific lectures at Harvard College, and later taught school at Concord, N. H.

In the process of time he became a distinguished scientist and philanthropist, and for his researches was renowned in Bavaria, Great Britain and the United States. An outstanding achievement was the overthrow of the then prevailing caloric theory of heat and the substitution for it of the dynamical theory.

Created a prince by Prince Maximilian, he chose the title "Count Rumford" from Rumford, N. H., now Concord.

In a letter dated July 12, 1796, to John Adams, then president of the American Academy of Arts and Sciences, Count Rumford wrote as follows:

> Sir,—Desirous of contributing efficaciously to the advancement of a branch of science which has long employed my attention, and which appears to me to be of the highest importance to mankind, and wishing at the same time to leave a lasting testimony of my respect for the American Academy of Arts and Sciences, I take the liberty to request that the Academy would do me the honour to accept of Five Thousand Dollars, three per cent. stock in the funds of the United States of North America, which Stock I have actually purchased, and which I beg leave to transfer to the Fellows of the Academy, to the end that the interest of the same may be by them, and by their successors, received from time to time, forever, and the amount of the same applied and given once every second year, as a premium, to the author of the most important discovery or useful improvement xxx on Heat, or on Light; the preference always being given to such discoveries as shall, in the opinion of the Academy, tend most to promote the good of mankind.

The receipt of this gift of $5,000 to the academy proved even more far-reaching in its influence than Count Rumford had anticipated. The principal of this fund now stands in excess of $84,000. The proceeds are used not only for the Rumford Medals but also for Rumford Grants for the purchase of apparatus by those who are conducting researches in heat or light.

The first award of the Rumford Medals was made in 1839, just one hundred years ago. To the present time 38 individuals have received this honor. On the list of "Medalists" of thirty years ago, we find the names of, among others, Alvan Clark, Henry Augustus Rowland, Albert Abraham Michelson, Edward Charles Pickering, Thomas Alva Edison, James Edward Keller, Elihu Thomson, George Ellery Hale, Ernest Fox Nichols and Edward Goodrich Acheson.

On October 11, 1939, the thirty-ninth award was made to Professor George Russell Harrison, professor of physics at the Massachusetts Institute of Technology.

The committee felt unquestionably justified in its action for the following reasons: Although Professor Harrison is as yet a young man he has, in the last seventeen years, published thirty-five papers *in his own name* and eleven in collaboration with others; and he has recently written a book "Atoms in Action"—these forty-seven publications being all extremely valuable and, almost without exception, in spectroscopy, which is to-day one of the most important branches in the science of light.

PROFESSOR GEORGE RUSSELL HARRISON.
PROFESSOR OF PHYSICS AND DIRECTOR OF THE RESEARCH LABORATORY OF EXPERIMENTAL PHYSICS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

The outstanding achievements, in which Professor Harrison's mind has been the guiding influence, are three:

First. The development of an "automatic wave-length comparator," a machine which automatically measures, reduces and records wave-lengths and superposes upon the film on which these are recorded a microphotometer trace which shows the intensity and physical characteristics of the lines. Complex spectrograms may thus be measured from 10 to 200 times as fast as was hitherto possible. With the aid of this instrument a volume of wave-length tables covering 109,725 lines has been prepared.

To those spectroscopists who for hundreds of hours in their lives have been seated at the microscope, estimating visually the intensities of spectrum lines appearing on the photographic plate, setting the cross-hairs of the comparator upon these lines and later laboriously

calculating their wave-lengths, it appears nothing short of miraculous that this new machine performs synchronously the three processes above mentioned and completes the operations in but a fraction of the time previously required.

Second. The invention of an automatic subtracting machine for sorting wave-number intervals, for use in the analysis of atomic energy levels.

Third. The production of an interval sorter, which takes the intervals shown by the second machine to be important and combing wave-length lists very rapidly, picks out all pairs of lines showing these intervals.

The development of these three machines alone, apart from numerous other achievements, constitutes a contribution to the field of spectroscopy, which places the most recently elected Rumford Medalist quite properly among the brilliant and distinguished scientists who have been recipients of this honor.

It may be of interest to the public to know that, at this October meeting, the American Academy, for the first time in its history, "went on the air." Dr. Harlow Shapley, director of the Harvard Observatory and president of the academy, presided; the medals were presented by the writer of this article; and Dr. Harrison then delivered an address upon the subject, "New Methods in Spectroscopy."

N. A. KENT

BOSTON UNIVERSITY

ONE OF THE MEDALS GRANTED TO PROFESSOR HARRISON.

SEEDLESS FRUITS PRODUCED BY CHEMICALS

EVERY one is familiar with the fact that there are seedless fruits as, for instance, oranges, grapes, bananas and even cucumbers, but it is perhaps not so well known that it is possible to produce seedless fruits artificially by treating the flowers with chemicals. To be sure, not every plant can be made to produce fruits by this treatment, but success has been attained with a good many species.

The tomato was the first seedless fruit successfully produced by chemicals. When the flower buds were nearly ready to open they were opened with a pair of forceps and the pollen-bearing stamens removed. Upon the pistil or sometimes upon the cut surface of the style was placed the chemical mixed with lanolin (fat from sheep wool). The lanolin served merely as a carrier for the

chemical. The bud was closed again, and in a rather high percentage of treatments there resulted a fruit which was perfectly normal in every way except there were no seeds. Sometimes the fruits were small and solid without any seed cavities, but that was rather unusual. The taste of these seedless fruits was no different from that of the seeded fruits.

Peppers, crookneck summer squash, egg plants and watermelon have been produced in a similar way. Not only fleshy fruits but also dry fruits have been produced by treating the flowers with chemicals. By injecting a dilute solution of the chemical into the pistil of the flower, tobacco fruits were produced that were nearly full size, but without seeds. Another variation of the method has been to spray the flowers with the chemical. This method has usually been employed with plants that have the two sexes in separate flowers, in which case there is no necessity of removing the stamens. Seedless holly berries and strawberries have been produced by spraying the flowers.

The chemicals which have been found to be effective are phenylacetic acid, indole-acetic acid, indole-butyric acid and naphthalene acetic acid. These chemicals, together with a number of others, have been found to produce growth in plants and are generally spoken of as growth-promoting substances. Several of them have been used to produce roots on cuttings.

Extracts of pollen from several plants have also been used to produce seedless fruits. The extract was mixed with lanolin and the paste applied to the pistils with the result that in many instances fruits resulted.

Besides producing seedless fruits, which may or may not be of any significance in itself, these experiments are of considerable scientific importance because they furnish the botanist with much-needed information about the development of fruits. Recent investigations have shown that there are naturally occurring growth-promoting substances, or hormones, in flowers and fruits. It has been found that the pistil, pollen and the seeds contain a considerable quantity of growth hormones, and it was further discovered that the pistils from varieties of oranges and grapes that naturally produce seedless fruits

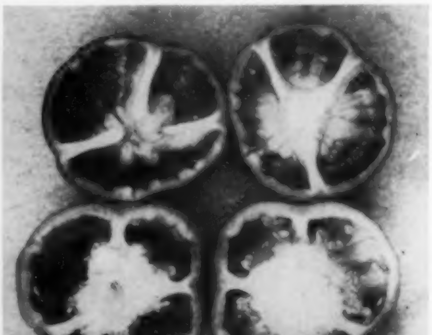


FIG. 1. EFFECT OF BUTYRIC ACID ON PEPPER FRUIT SEED DEVELOPMENT. (*Left*) THE PEPPER FRUIT WITH THE TAG WAS PRODUCED BY TREATING THE FLOWER WITH INDOLE BUTYRIC ACID. THE OTHER FRUIT IS NORMAL. (*Right*) THIS REPRESENTS CROSS SECTIONS FROM THE PARTHENOCARPIC FRUITS IN THE ADJACENT PICTURE. NOTE ABSENCE OF SEEDS. THE LOWER FIGURES REPRFSENT NORMAL FRUITS WITH SEEDS.

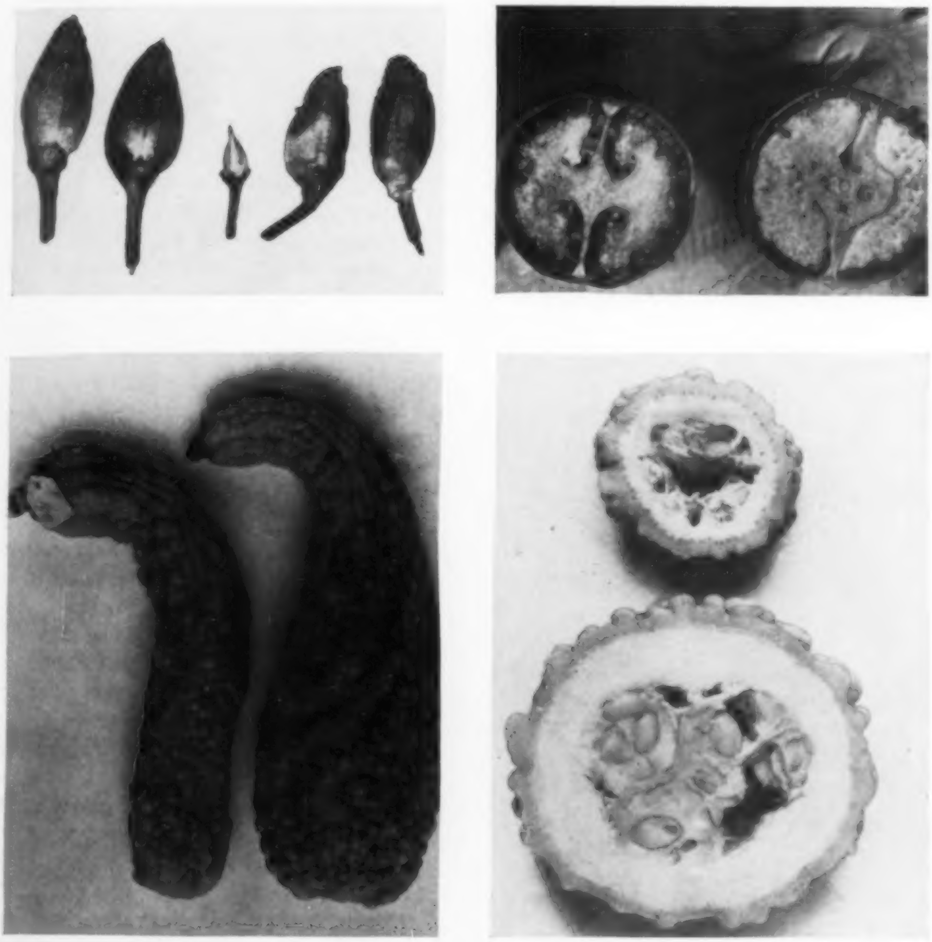


FIG. 2. EFFECT OF ACID ON SEED DEVELOPMENT.

(*Top left*) THE MIDDLE FIGURE REPRESENTS THE ORIGINAL OVARY OF A TOBACCO FLOWER. THE FRUITS ON THE LEFT WERE PRODUCED BY POLLINATION AND THE ONES ON THE RIGHT BY TREATING THE FLOWERS WITH THE POTASSIUM SALT OF INDOLE ACETIC ACID. (*Top right*) THE FIGURE ON THE LEFT IS A CROSS SECTION OF THE FRUIT SHOWN ON THE LEFT IN THE ADJACENT PICTURE, WHILE THE ONE ON THE RIGHT WITHOUT SEEDS IS A CROSS SECTION OF THE FRUIT ON THE RIGHT IN THE SAME FIGURE. (*Bottom left*) THE CROOKNECK SUMMER SQUASH WITH THE TAG WAS PRODUCED BY TREATING THE FLOWER WITH INDOLE BUTYRIC ACID, WHILE THE FRUIT ON THE RIGHT IS A NORMAL FRUIT. (*Bottom right*) THE UPPER FIGURE WITHOUT SEEDS IS A CROSS SECTION OF THE PARTHENOCARPIC FRUIT WITH THE TAG IN THE ADJACENT PICTURE. THE LOWER FIGURE IS A CROSS SECTION OF A NORMAL FRUIT WITH SEEDS.

contain more growth hormone than the pistils from varieties that do not produce seedless fruits. Unlike the seeded fruits, the seedless fruits are produced without fertilization and in many cases even without pollination.

Based on these findings, a hypothesis of fruit development has been formulated. It has been suggested that normally the pollination and the development of the pollen tubes bring into the ovary a quantity of growth hormone which, together with that which is already present in the pistil, is sufficient to start the fruit growing. (Without pollination there will be no fruit development.) The developing embryo in the seed may either produce more hormone or cause it to flow into the fruit from the leaves to supply the hormone needed for the continued growth of the fruit. On the other hand, in some varieties of oranges and grapes the pistil contains enough hormone to initiate growth without pollination and fertilization, and here we have produced seedless fruits.

These experiments, though scientifically interesting and important, have probably no commercial value. It would be too expensive to treat each individual flower separately and that would as a rule be necessary. Attempts have been made to produce seedless dates with chemicals, but so far without any success. If success were attained with this plant, it would be a commercial advantage.

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INDUSTRIAL RESEARCH IN THE UNITED STATES

A GENERATION or two ago the word *science* became so highly respected that it was applied to all sorts of things, whether or not they had any relation to scientific work. Even athletes, such as boxers, who had certain characteristics were said to be scientific. More recently *research* has come to wear the purple. In our universities it is rolled unctuously on the tongues of those who have seen it only from afar. It is honored in industry, finance and government. There is no other pillar of fire to guide us out of the night.

For 30 years the center of gravity of scientific research has drifted from our universities toward our industries, and now the current is becoming strong toward governmental agencies. All these trends arouse reflections. At the moment, however, we may review the magnitude of industrial research.

In 1938 there were 1,769 industrial research laboratories in the United States employing about 30,000 persons. The estimated annual expenditure of these laboratories is $100,000,000, with a wide margin of uncertainty. The chemical industries employ more scientists and pay more for research than any other industries, the electric and communication industries coming second. Together these two industries account for nearly half of industrial research.

Without any basis for comparison, the persons employed in industrial research and the expenditures for it appear enormous. But only about one per cent. of manufacturing corporations maintain research laboratories and only one sixth of one per cent. of the value of their products is spent for research. In a sense, research is a sort of insurance. Considered from that point of view, the expenditures for it seem extremely small. Enormously more is spent for fire and other insurance; enormously more is spent for insuring a continuing supply of raw materials. Much more is spent for accounting and legal advice. Much more is spent even in preparing for governmental agencies the numerous reports required of corporations.

F. R. M.

INDEX

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